A VIEW on Mechanical Dissection for Freshmen Engineering

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Abstract – Mechanical dissection is an engineering activity that can satisfy a student's curiosity of how and why the components of a given device can convey specific motions to achieve a desired result. Hence, several university engineering programs have developed mechanical dissection laboratories. However, such laboratories are not always feasible due to the lack of space, personnel, time and high costs. An emerging trend to address this issue is to use multi-media technology to replace/supplement physical laboratories. The objective of this work is to develop the second phase of VIEW (Virtual Interactive Engineering on the Web) which is a virtual mechanical dissection module. Virtual dissection implemented in VIEW requires only the use of existing computer laboratories. This module is used as a supplement in the course: Introduction to Engineering. Further details including assessment results which indicate that the module was well received by students are discussed in the paper.

Keywords: virtual labs, mechanical dissection, freshmen engineering

INTRODUCTION

Student learning, success, and retention are significant challenges for many university engineering programs throughout the country [1]-[4]. In order to address this, engineering faculty continue to develop and adopt new computer and web-based technologies to improve instruction and student learning. This is especially effective given that most students today are comfortable with modern computers and technology. The recent development of the open software standard, X3D [5] is an example of a web-based virtual reality technology that can be used to enhance student learning across a broad range of applications including computer-aided design (CAD), visual simulation, medical visualization, geographic information systems (GIS), and for entertainment, educational, and multimedia presentations. The objective of this project was to develop and implement the second phase of a Web-based 3D computer graphics framework using X3D (Virtual Interactive Engineering on the Web - VIEW), dedicated to the advancement of instruction and learning in the engineering curriculum, and to further enhance student learning and retention efforts at Armstrong Atlantic State University (AASU).

The Engineering Studies Program at AASU 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 at AASU and then transfer to the Georgia Institute of Technology (G.Tech) to complete their bachelor's degree. Over the past four years, our program enrollment has averaged a total of 192 students majoring in civil, mechanical and

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electrical and computer engineering with approximately 20% of them successfully transferring to G.Tech to complete their degrees. Like many other engineering programs throughout the country, retention is clearly a challenge for our program. One reason many students leave engineering is because they are simply bored or lose interest in the field [4]. Hence, there is a need for more engaging learning environments such as those afforded by 3D Web-based graphics to help address the issue of retention in engineering education. The expansion and use of VIEW modules in applicable courses can help to reinvigorate students' excitement and interest in engineering.

The following sections present a brief background on the Extensible 3D standard, an overview of the project, a description of the course under consideration, a description of the mechanical dissection module, a summary of assessment, a few concluding remarks and an outline of 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 [5]. It can be used across hardware devices and in a broad range of applications including interactive simulations used for engineering education. 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 [6]. It improves upon VRML with new features, advanced Application Programming Interfaces (APIs), additional data encoding formats, stricter conformance, and a componentized architecture using profiles that allows for a modular approach to support the standard and permits backward compatibility with legacy VRML data.

Some additional features of X3D include [7],[8]:

- 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 in 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. A screen shot of the VIEW website is shown in the Appendix. Further details of VIEW can be obtained from the following URL: http://cs.armstrong.edu/felix/projects/VIEW/ .

The first phase of VIEW was the development of a Virtual Tensile Testing Laboratory (VTTL) used as a supplement in the course: Introduction to Engineering Materials (ENGR 2000). The VTTL was first 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 important concepts studied in this course [9],[10].

The second phase of project VIEW involves the development of a module introducing the concept of mechanical dissection and/or assembly to supplement the course Introduction to Engineering (ENGR 1100). Mechanical dissection or the process of disassembling and reassembling devices and mechanisms is an engineering activity that can satisfy a student's curiosity of how and why the components of a device can convey specific motions to achieve a desired result [11]. As a result, several university engineering programs have developed mechanical dissection courses/labs. However, such laboratories are not always available due to the lack of space, high costs and time constraints. An emerging trend to address this issue is to use multi-media technology to replace and/or supplement physical laboratories [12],[13]. Virtual dissection or assembly activities implemented as part of VIEW would only require the use of existing computer laboratories. These labs will benefit courses such as Introduction to Engineering (ENGR 1100) and Creative Decisions and Design (ENGR 2110).

Course Description: Introduction To Engineering

Introduction to Engineering (ENGR 1100) is a 3-credit hour course taken by all freshmen engineering students, in which students are introduced to the engineering process from problem formulation to the evolution of creative design.

A few of the objectives of this course is to

1) excite students about engineering,
2) cultivate problem-solving skills,
3) encourage creativity,
4) cultivate professionalism, and
5) emphasize the importance of communication skills.

One approach to objectives (1)-(3) is through the use of mechanical dissection/assembly activities. However, this is often difficult to implement in our pre-engineering program with no direct access to laboratory space, equipment and personnel. In order to address this issue, the mechanical dissection module in VIEW was developed and is being used as a supplement in this course.

The Mechanical Dissection Module: A Mechanical Power Toothbrush

The first model to be developed in the mechanical dissection module was a mechanical, power toothbrush. Figure 1 shows the assembled model of the toothbrush on the left and the dissected model with all the parts on the right. The 3D CAD models of the parts and assembly were modified using SolidWorks [14] and then imported into the X3D format. The models were originally created as part of the Cyber-Infrastructure-Based Engineering Repositories for Undergraduates (CIBER-U) project [15].

The toothbrush model was selected because of its current use in another engineering course: Creative Decisions and Design (ENGR 2110) where mechanical engineering students are taught in further detail the important concepts of mechanical dissection and its use in the engineering design process. Students in ENGR 2110 currently disassemble and reassemble an actual toothbrush and write a report on the functions of the various components of the toothbrush.

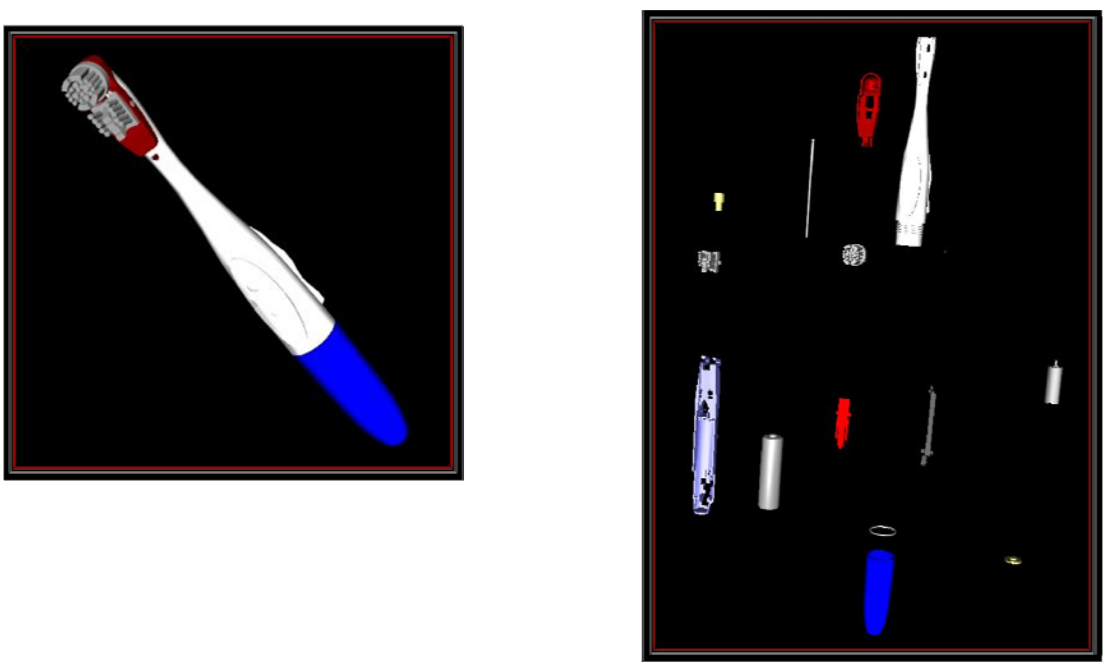

Figure 1: Model of a Mechanical Power Toothbrush

The Graphical User Interface

In addition to X3D, implementation of the power toothbrush's simulator primarily relies on two other key components: PHP and JavaScript. PHP is the scripting language for generating web pages and JavaScript is the scripting language that provides the interaction between the elements of the graphical user interface (GUI). Further, ECMAScript standard is used to program scripting nodes in X3D files, and Asynchronous JavaScript and XML (AJAX) technology is used for asynchronous access to the server-side data, as explained in the following paragraph.

The GUI of the power toothbrush's simulator as illustrated in Figure 2 is constructed of HTML controls, a virtual 3D scene, and a controls panel. The user can select any part of the model (via a drop down menu), which can then be viewed and examined individually in order to discern the role and function of each part in the final assembly. The simulator begins with the disassembled view of the power toothbrush. The user can start a session using an html control button and begin the assembling process by selecting each part and dragging it towards the assembly using the mouse and cursor keys. A view of the assembled model is also accessible to the user during the simulation. As shown in Figure 2, a scoring scheme with a timer was also implemented in the simulator. Penalties associated with errors in the assembly process - such as wrong order of assembly or wrong positions are built into the scoring scheme. A buzzer and a flashing red screen serve as indicators of such errors. A 'click' sound and a green flashing screen indicate a correct positioning of a part. The scoring scheme and timer were used to emulate a gaming scenario as much evidence exists to support the efficacy of digital game-based learning environments [16]-[19]. After completion of the assembly, a report is generated with the user's name, course information, final score, and time taken for the assembly process.

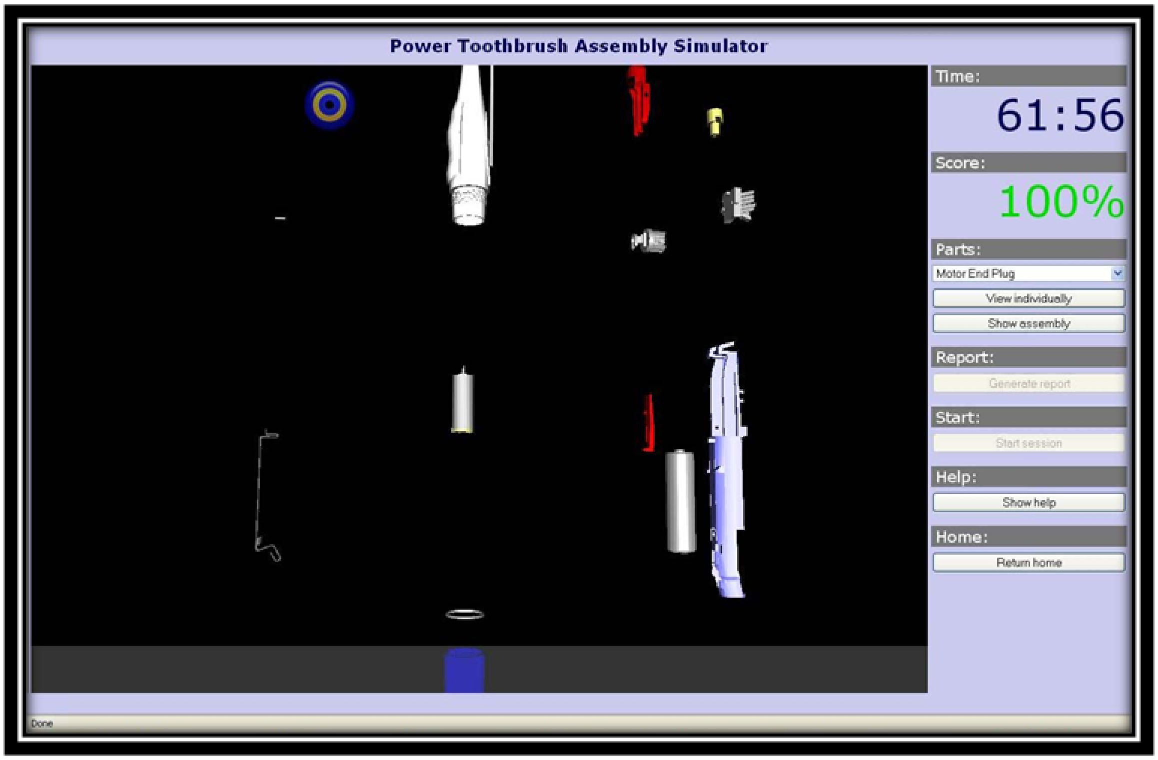

Figure 2: The Graphical User Interface for the Mechanical Power Toothbrush's Simulator

The Mechanical Dissection Module Implemented in Introduction to Engineering

The VIEW modules for mechanical dissection in ENGR 1100 were implemented as team projects in Spring 2009 and Fall 2009. The project consisted of four phases which each team (3-4 students each) completed over the course of four 50 minute class periods. The following is a summary of the tasks given to the students in each of these phases.

Phase 1: This phase was completed individually by each student. Students were asked to develop and sketch a simple preliminary conceptual design of a mechanical, power toothbrush adhering to constraints of simplicity of use, minimum hand movement required, etc. The preliminary design was required to have 5 or more parts with a brief description of the functions/roles of the parts in the overall design.

Phase 2: This phase was completed by each team. Students were asked to study the preliminary designs developed by individual team members, select two of the designs, and further develop detailed designs with sketches and descriptions clearly showing how the motor conveys the appropriate motions to the other parts of the design, etc.

Phase 3: This phase was completed individually by each student. First, students were given a brief tutorial and overview of the mechanical dissection module in VIEW using a mechanical dissection of a simple cube as an example. They were then asked to develop the assembled model of the power toothbrush using the simulator and submit a copy of the final report with their final score and time taken. In addition, each team was asked to note the various parts in the assembly with emphasis on how these parts should connect with the final assembled product.

Phase 4: This phase was completed by each team. Students were asked to examine and select one of the two detailed designs developed in phase 2. They were then asked to develop a detailed design with appropriate modifications based on concepts/ideas learnt from the previous phases. A detailed sketch and description of the final design was to be submitted at the end of this phase. An example of a design submitted by one of the teams is shown in the Appendix.

It is noted here that the above phases are based on the engineering design process which is introduced in this course. The students were graded on their work in each phase.

ASSESSMENT

To assess the effectiveness of the module, 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 from the survey results shown in Table 1, that 100% of the respondents in Spring 2009 and 96% of the respondents in Fall 2009 strongly agreed or agreed that the use of interactive 3D models in engineering courses would help them better understand course material. In addition, a similar majority of the respondents in both semesters strongly agreed or agreed that the 3D models help them to better visualize and understand the relationship between mechanical dissection and design. The 'computer game' scenario used in the simulator was also received well by majority of the students.

Questions	**Options**	**Spring 2009 # of responses (% of N=18)**	**Fall 2009 # of responses (% of N=48)**
The use of interactive, 3D models in current engineering courses will help me to better understand the course material.	Strongly agree Agree Disagree Strongly disagree Not applicable	10 (55.56%) 8 (44.44%) 0 0 0	23 (47.92%) 23 (47.92%) 0 1 (2.08%) 1 (2.08%)
I will gain more insight into the relationship between mechanical dissection and realize the design intent of each component by drawing, editing and grouping objects with an interactive 3D software program.	Strongly agree Agree Disagree Strongly disagree Not applicable	14 (77.78%) 4 (22.22%) 0 0 0	15 (31.25%) 31 (64.58%) 1 (2.08%) 1 (2.08%) 0
The use of virtual engineering labs/modules will help to supplement the need for more 'hands on' projects and labs in the course.	Strongly agree Agree Disagree Strongly disagree Not applicable	10 (55.56%) 7 (38.89%) 1 (5.56%) 0 0	9 (18.75%) 26 (54.17%) 11 (22.92%) 1 (2.08%) 1 (2.08%)

Introducing virtual engineering labs/modules will only make the curriculum more complicated.	Strongly agree	1 (5.56%)	3 (6.25%)
	Agree	0	4 (8.33%)
	Disagree	8 (44.44%)	29 (60.42 %)
	Strongly disagree	8 (44.44%)	11 (22.92%)
	Not applicable	1 (5.56%)	1 (2.08%)
The 'computer game' scenario used in this module helps me to evaluate and learn about the various components used in the overall design of the product.	Strongly agree	11 (61.11%)	10 (20.83%)
	Agree	7 (38.89%)	28 (58.33%)
	Disagree	0	7 (14.58%)
	Strongly disagree	0	0
	Not applicable	0	3 (6.25%)

Table 1: Summary of results from the survey for Spring 2009 and Fall 2009.

Students' general comments are shown in Table 2. One of the objectives of Introduction to Engineering (ENGR 1100) is to excite students about engineering. The written comments from students in Table 2 show that this module helped in meeting this course objective.

Other Comments	**# of similar responses to each comment**
"The program used was well thought out and very effective. It gives a new look to learning parts of the object which sparks more interest." "I think using hands on approach will help me in the overall undertaking of MECH classes" "If we had this in the beginning, the class would have been more funner and easier" "I'm glad I am going to be an engineer!" "Learning how the toothbrush was assembled and actually doing it was a great idea. All of the 'hands on' stuff like the computer programs and drawing and working with classmates to design something was also great" "Definitely a helpful addition to classroom learning but should not replace actual 'hands on' labs"	2

Table 2: Other written comments from students in Spring 2009 and Fall 2009.

It was also observed from Table 1, that the overall response was only 5.56% negative (1 out of 18; 2 questions) in Spring 2009 and 2.08% -14.58% negative (1-7 out of 48) in Fall 2009 with about 25% saying that the use the virtual labs/modules will NOT help to supplement the need for more 'hands on' projects and labs in the course. In response to this and the last comment in Table 2, it is noted that these virtual modules are designed to be used only as supplements in certain freshmen courses. Students are exposed to actual 'hands on' mechanical dissection activities later in the curriculum in courses such as Creative Decisions and Design (ENGR2110). Furthermore, the disparity in the overall responses between the spring and the fall semesters can be attributed to the general diversity in academic backgrounds (especially in this course), in the student body between the spring and fall semesters. The students enrolled in ENGR1100 in the spring semester have an overall lower academic standing (based on GPA, SAT scores and the level of math/science completed) as compared with those in the fall semester. This disparity is amplified by the fact that 75% of the students enrolled in this course in the fall semester are G.Tech students (dual enrolled at G.Tech and AASU), compared with only 5% of the same in the spring. Further assessment in subsequent semesters would be useful to identify any relevant trends. In order to address this issue, the authors propose to develop other modules with relatively complex mechanisms to challenge and engage students with different backgrounds. While the students from both semesters had a strong perception of an improved understanding of course material, the authors look forward to developing additional assessment tools to gauge the actual level of impact on student learning to accompany the more challenging VIEW dissection modules.

In addition to the surveys, the design schematics and descriptions submitted after every phase were evaluated to assess the effectiveness of the module on student learning. It was observed by the instructors (first two authors) that the students developed a good understanding of the functions and roles of all the parts in the final product, and were extremely creative in their designs with an emphasis on crucial details important in such a product. This creativity and attention to detail was also implemented in a final design project completed by the students during the last 4-6 weeks of the semester.

CONCLUDING REMARKS AND FUTURE WORK

This paper presents a summary of the recent developments in the second phase of project VIEW: A module on mechanical dissection. This module was completed and successfully implemented in Spring 2009 and Fall 2009. The results of the surveys, student comments and student performance show that the module was well received by the students. In addition to the benefits mentioned in the above section, students also learned the importance of individual and team brainstorming sessions, professional communication, and other team working skills.

Introduction to Engineering (ENGR 1100) is taught every semester with an average enrollment of 100-125 students per year. The modules developed will continue to be used in subsequent semesters. Student surveys, including individual comments from students, and relative student performance will be used to evaluate and assess the impact of this work.

This work also lays the foundation for the development of additional virtual laboratories/teaching modules for other courses. For example, the development of the 3D CAD models for this project will also be presented as an application case study in the course Engineering Graphics (ENGR 1170), in which students learn SolidWorks [14]; and a modified mechanical dissection module can be developed for the course Creative Decisions and Design (ENGR 2110). Virtual laboratories can also be applied to courses in other disciplines in the appropriate context, for example chemistry: molecular and crystal models, history: a virtual exploration of an archeology site, arts: 3D art representation and creativity and geography: 3D explorations of natural phenomena. The World Wide Web will continue to be used for dissemination. Based on assessment results and subsequent improvements to VIEW, it is proposed that these modules will be freely available to the general engineering education community.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the MATH + SCIENCE = SUCCESS AASU STEM Initiative Grants Program 2008-2009 for providing the required funding for this work.

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Appendix

A screen shot of the web-site: http://cs.armstrong.edu/felix/projects/VIEW/mechanicalDissection/

An example of a design submitted by one of the teams in ENGR 1100, Spring 2009: