Development of a CAI for use in an Industrial Biomechanics and Ergonomics Course

Nicole Washington, Mohamad Parnianpour, and Jared Walkenhorst
The Ohio State University, Columbus, Ohio

Abstract
Multimedia technology offers a more interactive approach to instruction than the traditional classroom lectures. Through computer-aided instruction (CAI), a number of teaching styles can be used that take into account the different preferences of the students. The Biomechanics Tutorial program, is a CAI that incorporates audio, video, simulations, and graphics to: review concepts of mechanics (kinematics and kinetics of interconnected rigid bodies), familiarize students with functional anatomy, and allow students to interactively evaluate the law of mechanics applied to physical performance of activities modeled by a set of biomechanical models of the joints. Principles of ergonomics are reinforced by enabling the student to perform numerous numerical experiments within the context of workplace or task redesign and see the real time consequences of these alterations. For example, the task of holding a handle is simulated by allowing the student to change elbow and shoulder angles and the orientation and magnitude of the load. The consequences of these in terms of required muscle forces and joint reaction forces at the elbow and shoulder will be updated on the screen. The detailed rationale, development stages, and key examples of the tutorial will be presented.

I.   Introduction

Aside from education, computer-aided instruction (CAI) is being integrated into several post-collegiate arenas. Automobile maintenance, the art of handling personnel, and programs to teach cardio-pulmonary resuscitation are a few of the job training programs that have used this method of instruction [2]. With the increasing growth of computer technology world-wide, it is imperative that collegiate education meet the challenge of graduating students with hands on experience in using existing software packages and with the critical thinking skills of how to physically apply the knowledge they have gained in the classroom. The Biomechanics Tutorial, developed in house, expedites the transition from lecture to application for students in an introductory biomechanics class. It reviews basic concepts of rigid body mechanics and functional anatomy and combines them in a way that the student can become confident and efficient in building biomechanical models.

II. Review of the Design

The Biomechanics Tutorial is designed to allow the user to smoothly navigate the various sections in either a linear or nonlinear fashion. Linear navigation by the user is supported by the sequential outline of the primary contents and the sub contents of the tutorial. Nonlinear navigation is supported by the hypertext functionality of each section's outline which allows the user to proceed throughout the tutorial in the order he/she chooses. This hypermedia option is available throughout the tutorial so that the user is also able to navigate within each section as he/she chooses.

The Biomechanics Tutorial contains a *mechanics review*, a *mechanics quiz*, an *anatomy review*, an *anatomy quiz*, *quiz results*, examples of *simulations*, a *study guide*, and practical biomechanical simulations that are presented as laboratory exercises for students to explore and analyze.

A. Review Sections

This section is designed to review basic engineering mechanics principles. It contains hypertexted concepts such as units of measurement, vector operations, and Newton's laws. When the user clicks on a particular text, the tutorial jumps from the present screen to a screen containing information that describes that particular concept using a combination of text and colorful graphics.

At the beginning of this section is the sequential outline of its contents. The instructions on this screen directs the user to explore the contents of the outline by clicking on the hypertext or by using the pull-down menu to navigate to other parts of the tutorial. Within the screens or pages of the mechanics review are buttons that allow the user to loop through each particular section of the outline or to navigate back to the outline to proceed to another section.

The *anatomy review,* similar in structure to the *mechanics review*, is included to familiarize the students with basic anatomy concepts. This section presents the students with anatomy material that will be useful when analyzing the different lab simulations.

B. Quiz Sections

The *mechanics quiz* tests the student's comprehension of the material presented in the *mechanics review*. The quiz is structured to randomly select 5 questions from a pool of questions that are specific to the mechanics review. Most of the questions are accompanied by a colored illustration and are individually placed on separate pages of the quiz section so that the user is not distracted by any extraneous material on the screen.

When the user selects a response to each of the multiple choice questions, the tutorial provides immediate feedback that either confirms the user's correct selection or presents him/her with the correct answer. Each correct response by the user was also followed by an audio, "Yea!" The user is able to navigate through the quiz section by pressing the continue button which appears with the feedback given after each response.

The *anatomy quiz* format is identical to that of the *mechanics quiz* with one exception. Because the *anatomy review* material is relatively dense and new to most of the students, there is an anatomy quiz that corresponds to each section of the *anatomy review* outline.

C. Quiz Results Section

The *quiz results* section is provided to give the student a sense of how well he/she is recognizing or absorbing the review material. This section is divided into 6 pages. There is a page to accompany each quiz as well as a page that prints the results of the student's performance on all of the quizzes combined. Each page of the *quiz results* section prints a message that includes the total number of questions the student was given from that particular section, the number of questions the student answered correctly and the number of questions the student answered correctly on the first try. The latter statistic is important since some of the questions may be randomly duplicated.

Students have several means of accessing the quiz results section. Firstly, each individual quiz concludes with its respective quiz results page. Once the tutorial is on this page, the user can go

to the main menu by pressing the "Main Menu" button that appears at the end of the message or by choosing "GoTo" from the pull-down menu and selecting "Main Menu." The student is also able to retake the quizzes, go to a different quiz, go to either of the review sections, or chose any of the lab exercises by choosing that particular item from the pull-down menu. If the student would like to view his/her results form other quizzes or view the overall quiz results at this time, he/she would simply click the right arrow button which loops through the pages of the quiz results section (Figure 1).

D. Simulations and Lab Exercises

The *simulation examples* section is included to give students a sense of the capabilities a the Working Model software. Simulations in this section are Quicktime movies that were made from some of the example files included in the Working Model version 4.0 application files.

The *lab exercises* contain practical simulations designed by the authors to highlight basic biomechanical principles (Figure 2). Students can access this section by choosing a lab from the main menu screen or from the pull-down menu. Once a lab is chosen, the tutorial is designed to enter directly into the Working Model application file that contains that particular lab simulation.

Each biomechanical simulation screen contains text that informs the student of the variables he/she can control on the model and advises them of what reactions to notice that may correspond with the changes made. The models used for these lab exercises get progressively more complex. The models range from a one joint static simulation to a two joint dynamic simulation.

Figure 1. Screen capture from tutorial report of overall quiz results.

Run

2 JOINT MODEL - SHOULDER AND ELBOW FORCES

Notice the change in the elbow joint reaction force as you change the magnitude and direction of the red external force.

Force Magnitude (N)

6.00

Force Direction (rad)

4.71

Elbow Joint Reaction Force		
Fx	-17.599	N
Fy	-100.351	N
|F|	101.883	N

Bicep Tension	
|F|	125.148 N

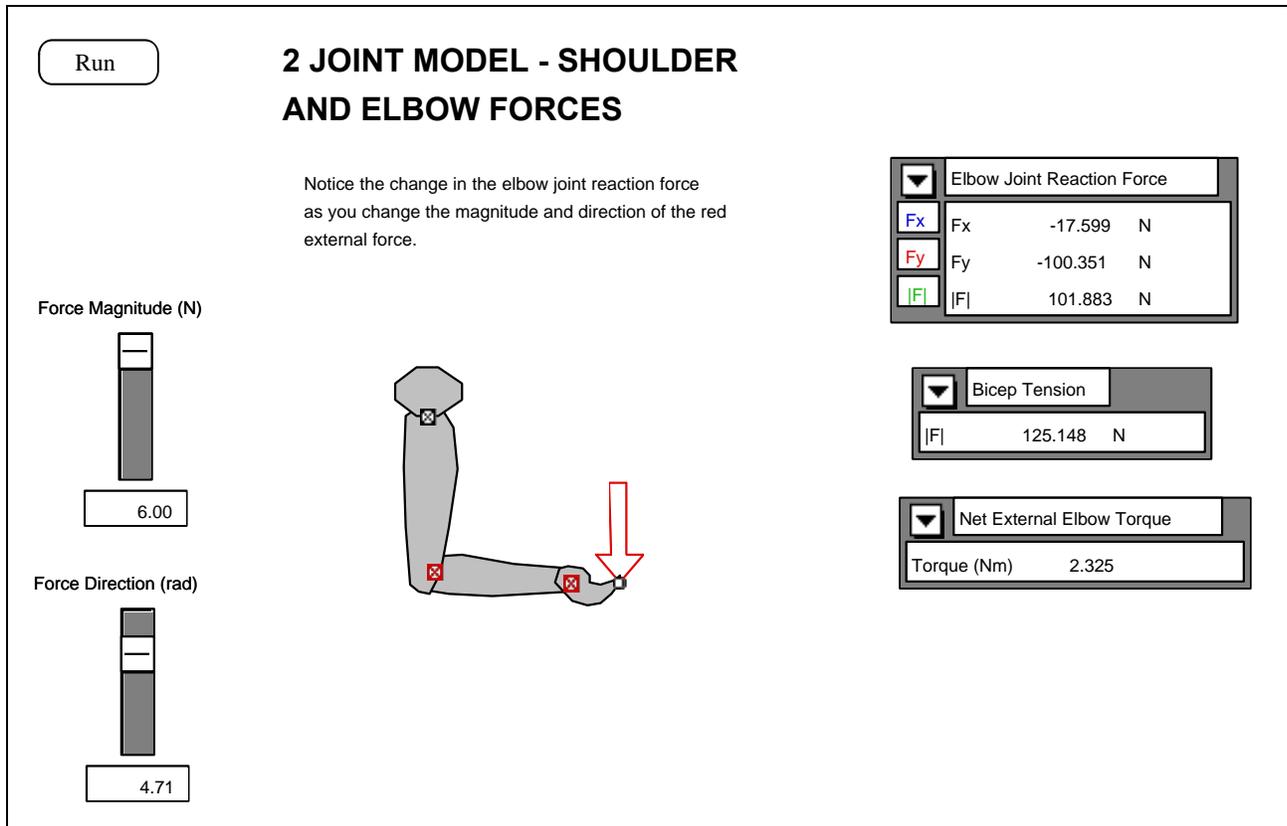| Net External Elbow Torque	
Torque (Nm)	2.325

Figure 2. Screen capture from lab exercise reviewing concepts of joint reaction force, bicep tension, net external elbow torque.

E. Study Guide

The *study guide* is presented in the tutorial as a recap of key material covered in the lectures and labs. It is merely an on-line reference source that students can use to access and copy study outlines and lab solutions. Each section of the guide begins with a screen that gives email addresses of the professor and the lab instructor for further questions or explanations. The screen(s) that contain the solutions or study material may be printed by pressing the print screen button that appears below other buttons of navigation.

III. Conclusions and Future Work

The Biomechanics Tutorial has had several cognitive evaluations and yet there are still some changes that could enhance its features. Firstly, the navigation throughout the tutorial could be more explicit. For example, as stated earlier, within the reviews the user is able to navigate through each section of the outline by selecting the "Next" button. "Next," however only allows the user to loop through that particular section, so the user has to go back to the first screen which contains the outline in order to access a different section. Also, by monitoring the percentage of questions completed successfully, the tutorial can be designed to only allow

students who complete the quizzes with an acceptable score to proceed into the Working Model section of the tutorial. This will ensure that the students have the background knowledge necessary to efficiently complete the assigned simulations using the Working Model application. Any previous knowledge the students are expected to have as they complete the tutorial is given in the reviews. It be may helpful to insert a page that informs the students that the reviews contain this prerequisite material and to explain the requirements for entering the Working Model portion of the tutorial.

Video excerpts accompanied with audio , will be implemented into the Working Model portion of the tutorial. It will be helpful for students to see footage of employees working in an actual workplace environment as they illustrate the particular movement that the user is asked to simulate. A narration that introduces the movement and explains the hazards of such would be heard throughout the short duration of the video.

The Biomechanics Tutorial will be reviewed by both individuals who are familiar with biomechanic concepts and those who may be more knowledgeable on the mechanics or the physiology components of the tutorial. After appropriate changes are made and the program has a satisfactory review as an instructionally and cognitively sound tool for students, we will conduct a quasi-experiment which considers the learning effects of CAI, using a class of undergraduates in the ISE 503 course. A quasi-experimental research design can be used when it is not possible to control all the conditions of an experiment [1]. A particular use for this method is in educational research which may make this design appropriate for our use.

References

1)McCuistion, P. J. Static vs. Dynamic Visuals in Computer-Assisted Instruction.
Engineering Design Graphics Journal, pp. 25-33, 1991.

2)   Matta, K. F. and G. M. Kern. A Framework for Research in Computer-Aided Instruction: Challenges and Opportunities. *Computers in Education,* **13**, pp.77-84, 1989.

Author Biographies

NICOLE WASHINGTON is a former graduate student of the Ohio State University. She is currently employed with Ernst & Young, LLP.

MOHAMAD PARNIANPOUR will be promoted to Associate Professor at The Ohio State University as of June 1997. He holds appointments in the Department of Industrial, Welding and Systems Engineering, Biomedical Engineering Center, Physical Medicine and Rehabilitation. His research interest include biomechanical modeling of neuromusculoskeletal system.

JARED WALKENHORST is currently a student at the Ohio State University pursuing his master's degree in Biomedical Engineering.