AC 2008-938: NEW COURSE DEVELOPMENT: BIOMECHANICS AND BIOMATERIALS FOR MECHANICAL ENGINEERING STUDENTS

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New Course Development: Biomechanics and Biomaterials for Mechanical Engineering Students

Abstract

Based on an ABET recommendation for our undergraduate Mechanical Engineering program, and interest from students a new course was developed to introduce Mechanical Engineering students to the topics of Biomechanics and Biomaterials. The course was designed from the beginning to include hands-on activities for students in addition to traditional format lectures. In-depth analyses of various human movements were performed by students using specialized computer software capable of computing and displaying kinematic and dynamic quantities of interest. The movements analyzed included students' own movements recorded during class with a camcorder and processed with the dedicated software. Students also had access to a library of previously recorded human motions provided with the software. The second part of the course was dedicated to biomaterials and their applications in medicine.

Recording and analyzing a human movement were part of a project completed by students as a course requirement. Students were also asked to research a biomaterial of their choice and describe its properties and medical applications in a scholarly paper. Finally students prepared presentations summarizing the analysis project and the biomaterial paper that were given to the entire class during the final class session.

From the first time the course was taught, it was well received by the students, who participated enthusiastically in the applied portions of the course. Creating our own library of motions for analysis, and adding a laboratory experiments component are some of the future goals for the course.

1. Introduction

Exposing our undergraduate Mechanical Engineering students to wider engineering topics, and specifically to Biomedical Engineering, was one recommendation made to us by ABET as part of the continuous improvement process of our program. Biomedical Engineering is an area of high growth according to the U.S. Department of Labor projections data for 2006-2016[1]. In response to this continued demand, many Biomedical Engineering programs have been added in universities across the United States. In addition, Biomedical Engineering is taught as part of the curriculum of other engineering disciplines as well[2], benefiting the students not only through the new knowledge they acquire in the area, but also through its essentially multidisciplinary aspects and wide range of applications.

At our institution we chose to introduce Mechanical Engineering students to the Biomedical Engineering area through a first course on Biomechanics and Biomaterials, both topics closely related to subjects in the Mechanical Engineering program. Biomechanics is a popular topic of study in undergraduate engineering at numerous universities, requiring fairly inexpensive computer software and laboratory equipment[3].

The paper describes the Biomechanics and Biomaterials course developed by the author as a technical elective for undergraduate Mechanical Engineering students. The course is a 4-hour credit course which includes lecture and hands-on activities. Course pre-requisites are Physics I (Mechanics) and Materials Science.

2. Topics and Course Requirements

The course is offered under the title of Biomechanics and Biomaterials, with the following course description: "Introduces students to the topics of biomechanics, and biomaterials used in medical applications. Students will use the principles of kinematics and dynamics to analyze and interpret a variety of human body movements. Includes survey of biomaterials, with properties and specific medical applications."

The following Student Learning Outcomes have been adopted for the course. Upon completion of the course students will have the ability to:

 1. Perform linear kinematics analysis and interpret position, linear displacement, velocity, and acceleration for a recorded motion.
 2. Perform dynamics analysis and interpret force and momentum for a recorded motion.
 3. Perform angular kinematics analysis and interpret angular displacement, velocity, and acceleration for a recorded motion.
 4. Perform dynamics analysis and interpret joint torque for a recorded motion.
 5. Analyze and interpret forces on human body in fluid medium.
 6. Compare properties of several different classes of materials, including metals, ceramics and polymers, for use in medical applications.
 7. Differentiate between types of biological responses to implanted materials.
 8. Research and prepare a scholarly paper on a biomaterial used in a medical application.
 9. Prepare and present in a professional manner a summary of results from analysis of a recorded movement of human body.

The course is a 4-credit hour course. The 40 class hours dedicated to the course under the quarter system at our institution are allocated as 29 hours for Biomechanics, 9 hours for Biomaterials, and 2 hours for student presentations of the analysis project and research paper.

The first part of the course is dedicated to biomechanics of the human body. The knowledge and skills students need in order to analyze motions of the human body can be divided in the following groups:
(i) knowledge of the structure and behavior of the musculoskeletal system, including types and functions of skeletal muscles and joints
(ii) knowledge of Newton's laws, and ability to solve problems involving statics and dynamics applications, including linear and angular motions
(iii) knowledge and skills using computer software dedicated to human movement analysis

One three-hour lecture has been used to introduce students to knowledge from the (i) group. The knowledge and abilities from group (ii) have already been acquired by students in their pre-requisite studies. A brief review has been conducted to refresh this knowledge, and further

application has been introduced through homework assignments consisting in problem solving involving the musculoskeletal system.

Acquiring group (iii) skills required students to work individually on computers in the lab under instructor's supervision. The specialized software chosen for this course is the KAVideo[4] software written by Professor R.E. Schleihauf from San Francisco State University (SFSU). The software performs 2D and 3D kinematic and dynamic analyses of pre-recorded human body motions, allowing the user to obtain detailed plots of quantities of interest for specific parts of the body. In addition to providing access to the extensive library of motions at SFSU, the software allows users to create their own data files from in-house recorded movies.

After students learned how to use the software using examples and exercises available on the software CD, we were ready to create and analyze our own motions. The recording of the students' motions in class was an exciting activity involving team work and also fun. One team was typically made of the student using the camcorder, the volunteer performing the motion, and the student responsible for the scaling information. The first time the course was taught we used only one camcorder, which restricted our motions to motions which can be analyzed in 2D. A 3D motion requires two camcorders recording the motion from two perpendicular directions, with the two movies needing to be synchronized for the analysis. The process to create the files in this case is more difficult, so we planned to go through it in future offerings of the course.

Figure 1 shows a computer screen associated with KA2D, the 2D analysis portion of the software. While the movie of the motion is played frame-by-frame, cursors show the current frame on the graphs. The graphs at the right show the position, velocity and acceleration of the desired segment of the body versus time, based on data available in the table at the bottom center of the image. For paper brevity, more examples of recorded movies and analysis screens will be presented at the conference.

Completing a project analyzing a body movement was one of the course requirements. Students used either the 2D or 3D software to look at a movement of their choice, and derive an interpretation of the characteristics of the movement. For this purpose they compared the movement with a movement performed by a skilled athlete in the case of a sports movement, or compared a rested vs. fatigued, or healthy vs. unhealthy way of performing the movement.

The second part of the course was dedicated to the study of biomaterials used in medical implants and medical devices. The classes of biomaterials discussed were metals, polymers, ceramics and composites. Three 3-hour lectures were dedicated to discussion of material properties, performance, cost and ease of manufacturing vs. requirements for implants and devices.

As a course requirement, the students were asked to research and write a paper on a material with biomedical applications of their choice. A very popular material, chosen by the majority of the students, was titanium and its alloys, with biomedical applications such as dental and skeletal bone implants, cardiovascular devices, surgical instruments, and recovery devices.

KA2D - epjjumper1

File Data View Help

Image count: 246
DG Mode: Normal

Kap File Information:
Cameras = 2D
CDf = 0
CDs = 0
Scale Length = 1.7
Film speed = 60
Rotation = 0
Autophase = On
Correct for tilt = Off
AutoDG = Off

Researcher: Edward Jakubik
Institution: Baker College Flint
Participant: Mark Warren
Condition: In shape
Smoothing: 5
Scale Factor: 0.00623245
Last Modified: 5/1/2007 8:28:56 PM
Project File: Jumper

Px/Py - Wrist   0.34   1.19

V - Wrist   0.62

A - Wrist   7.84

PlayBack Speed

Play

Step

39

Point

Segment

Joint

Wrist

☑ QwkStk
☐ QwkPic

Exit

Select a point / segment / joint for display:

Wrist	ForeArm	ElbowJT
Elbow	UpperArm	ShoulderJT
Shoulder	TrunK	HipJT
Hip	ThigH	KneeJT
Knee	ShanK	AnkleJT
Ankle	Foot	
Toe		
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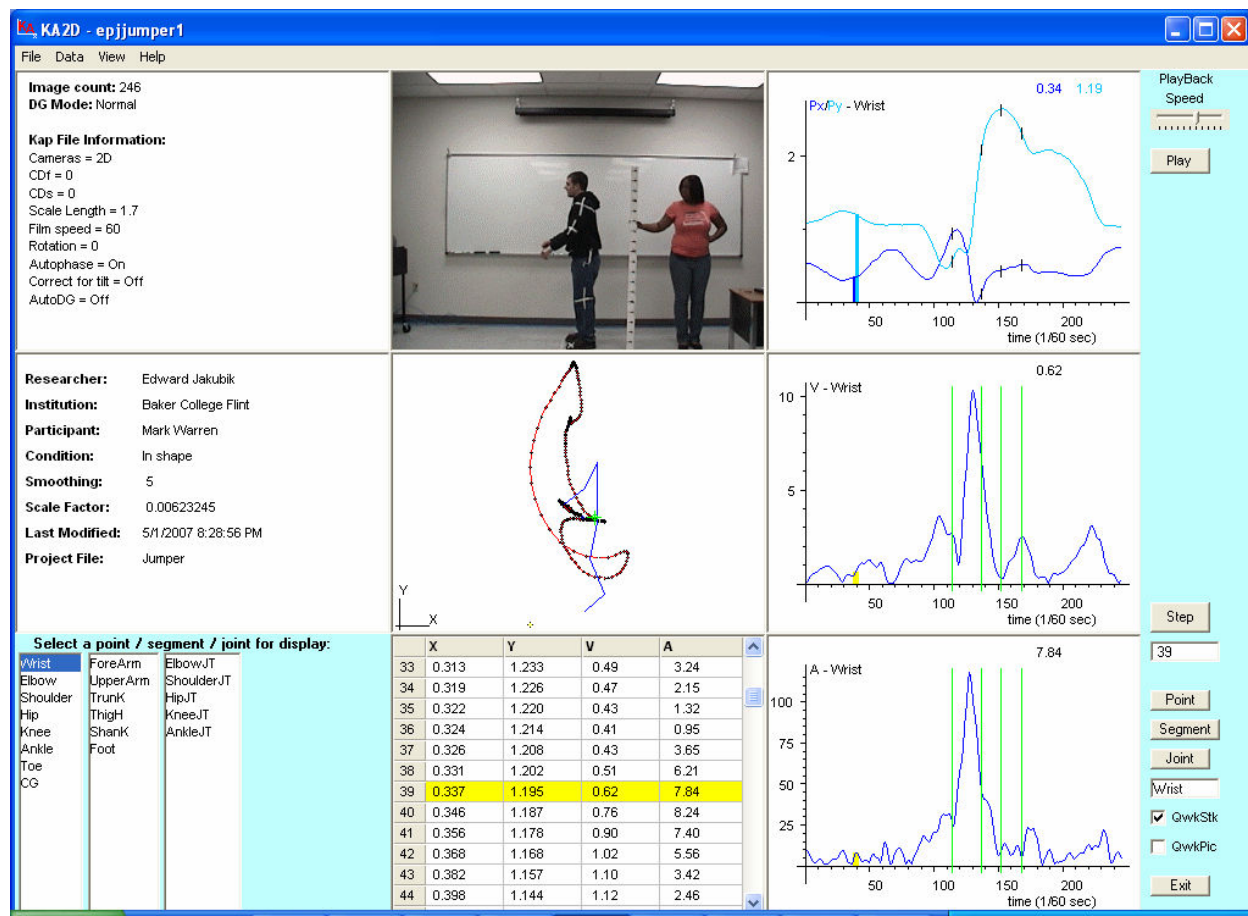|	X	Y	V	A
33	0.313	1.233	0.49	3.24
34	0.319	1.226	0.47	2.15
35	0.322	1.220	0.43	1.32
36	0.324	1.214	0.41	0.95
37	0.326	1.208	0.43	3.65
38	0.331	1.202	0.51	6.21
39	0.337	1.195	0.62	7.84
40	0.346	1.187	0.76	8.24
41	0.356	1.178	0.90	7.40
42	0.368	1.168	1.02	5.56
43	0.382	1.157	1.10	3.42
44	0.398	1.144	1.12	2.46

Fig.1 Computer screen from KA2D, two-dimensional analysis software.

The last class session was dedicated to student presentations of their work. Students used Power Point to present summaries of their analysis project as well as their biomaterial paper to the entire class and the instructor.

3. Assessment Results

The population of students enrolled in the course included one sophomore student, four juniors, and two seniors. The students worked in groups throughout the video recording sessions, but were required to complete all assignments individually.

Direct assessment data for the course was obtained from a variety of assignments that included homework, simulation labs, an analysis project, a biomaterial research paper, and the oral presentation of the main results obtained.

Homework assignments. The homework assignments required students to solve several sets of kinematics, dynamics, and fluid problems involving the human body. The problem sets were independent of the specific topics under study in a given lecture. Some help was available from the instructor with a few problems, but overall, students were capable of independently solving the problems by recalling knowledge and skills from previous study of Mechanics related

disciplines. The junior and senior students were the most successful in completing this assignment, with percentage scores better than 90%. Even though conclusions are difficult to derive with such a small population of students, it is likely that reinforcement of the skills throughout several disciplines was responsible for this.

Simulation labs. Simulation labs were conducted to familiarize students with the analysis software, and with further calculations of quantities of interest using excel spreadsheets. Directed exercises were assigned individually for students to complete during class time. Out of all assignments these were the easiest to complete by students, as they mostly stressed the data collection and manipulation, and in less measure the interpretation of the results.

Analysis project.

Table 1 lists the titles of the analysis projects and the research papers prepared by the seven students who took the class in Spring 2007.

Student	Analysis Project	Biomaterial Research Paper
1	Standing Vertical Jump	Titanium, the Miracle Metal
2	The Flying Right Front Kick	Titanium Bone Cement and Compression Ring
3	Vertical Jump	Bioactive Glass
4	Vertical Jump	Plastics Used in Biomedical Applications
5	Mark's Jump vs. The Big Jump	Titanium, the Miracle Metal
6	Heel Kick	Biodegradable Materials
7	Swimming Propulsion	Titanium as a Dental Implant

Table 1. Analysis projects and biomaterial papers for Biomechanics and Biomaterials course

The project required students to use either the 2D or 3D version of the software to analyze a movement of their choice, and derive an interpretation of the characteristics of the movement. For this purpose they could chose to compare movement with a movement performed by a skilled athlete in the case of a sports movement, or compare a rested vs. fatigued way of performing the movement. Most students chose to analyze a 2D movement recorded in class, and one student analyzed a 3D movement from the SFSU library. All movements were sports related, but at the end of the class students were able to suggest other areas of applications for this type of analysis, for example in automotive studies involving car occupants, and in ergonomics studies. The students showed a very good understanding of the components and the critical phases of the motion, and were able to perform detailed calculations of parameters using excel formulas. Choosing a familiar movement that students have extensive experience with is an important factor for a successful analysis.

Biomaterial paper. The classes of materials studied included metals, polymers, ceramics and composites, as applied in biomedical applications. We discussed material properties, interaction of the material with living tissues, and requirements for specific applications. For their research paper students picked a material of their choice and had to describe biomedical applications not covered in the course of the lecture. As shown in Table 1, four out of seven students picked titanium for their paper. Students did well in addressing advantages and disadvantages of each

material, and even proposing methods for circumventing some of the disadvantages. Overall students did very well in the content of their papers, but not as well using their technical writing skills. The topic is discussed often in department meetings and is under continuous scrutiny by faculty.

Oral presentations. Students compensated for some of their technical writing issues by creating very impressive power point presentations, containing animations and links to videos stored locally or on the internet. The instructor offered pointers during the oral presentations on how to improve students public speaking skills.

A summary of the direct assessment results is presented in Table 2, where the grade components, their weight, and the average score for the entire class in each category normalized to 100 are shown. Table 2 shows that students did very well especially in the simulation labs, the analysis project, and the oral presentation. The area where they had some difficulties was the scholarly paper, due to the quality of the technical writing as mentioned above. The instructor will stress the requirements for this next time the course will be offered.

Grade Component	Weight in final grade	Class Average Grade
Homework	15%	88
Simulation Labs	20%	97
Analysis Project	25%	91
Biomaterial Paper	25%	85
Oral Presentation	15%	91

Table 2. Final Grade Components and Class Averages

The target score for all percentage grades at individual level from all categories is at or above 70. The score range of 70-79 is considered 'satisfactory', 80-91 is considered 'good', and 92-100 is considered 'excellent'. All individual grades were above 70, with two exceptions. One student scored a 53 in the homework category, while another student scored a 62 on the project. Overall these two students performed at the 'good' level.

Course feedback from students was gathered using the institution's standard 'Course and Faculty Evaluation' form, administered at the end of the quarter for each course, as well as informal feedback through discussions with the students. The feedback showed that the course was well received by students, due to its interesting content, varied format, and opportunities for students' active participation. As the indirect assessment data obtained this way is not reliable and specific enough to allow for continuous improvement of the course, the author will prepare a course survey where students will be asked to rate their learning experience in this course vs. the Student Learning Outcomes, and comment on the usefulness of the course to their engineering education. The survey will be given to students the next time the course will be taught.

4. Conclusions

The course was well received by students, due to its interesting content, varied format, and opportunities for students' active participation. In addition to acquiring knowledge on

Biomechanics and Biomaterials, students honed their skills in the areas of computer simulations, scholarly research, team work, and oral presentation.

The course will be further improved by creating our own library of motions for analysis, and adding laboratory experiments to supplement the computer analyses. In the area of assessment, a student survey will be prepared and given to students to gather detailed data on students' perceptions of the class.

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