WEB-BASED LABORATORY MODULES FOR LINEAR AND ANGULAR KINEMATICS

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Two Web-based laboratory modules have been developed and implemented for reinforcing basic concepts in kinematics in the learning of biomechanics. In the linear kinematics module, students digitize the mid-hip, heel and toe on images showing the side views of sprinting, running and jogging and analyze the stride length and time and velocity among these actions. For the angular kinematics module, students digitize the near shoulder, hip, and knee on images of one complete revolution of a forward giant swing of a gymnast and determine the hip angle, the angular velocity and acceleration of the trunk. Evaluations and feedback from biomechanics instructors and students in biomechanics courses have suggested that these modules have the potential to be effective educational tools.

KEY WORDS: web-based digitizing system, linear kinematics, angular kinematics.

INTRODUCTION: Biomechanics of human movement, broadly defined as the science involving the internal and external forces acting on a human body and description of motion, including the pattern and speed of movement of body segments, is one of the required courses for students majoring in kinesiology, exercise science, and physical education. In this course, students are required to learn basic mechanical concepts, methods, and analysis techniques for human motion from course lectures and laboratory activities. Laboratory sessions are especially valuable for reinforcing concepts introduced in lectures. However, it has become increasingly difficult to acquire equipment, space, and personnel resources to manage laboratory sessions in higher education. Thus, a Web-based video digitizing system entitled Remote Interactive Motion Analysis System (RIMAS) has been developed for those programs that cannot offer laboratory activities because of budgetary, equipment, or space restrictions. The RIMAS system (www.rimas.net) provides unlimited accessibility and convenience in terms of both time (when) and location (where) to complete the laboratory experiences.

The RIMAS website has links to a number of laboratory modules for biomechanics and movement coordination. The system aims to provide the capability of performing digitizing (extraction of coordinates from the image) without using specialized equipment in laboratory settings. The steps involved in developing a module typically included (a) the development of the story-boards, (b) the generation of the video sequences (if applicable), (c) the writing of the laboratory documentation and instructions, (d) the coding of web pages, and (e) various processes necessary to get the material up and running on the web. Current web technology has been used in this project to enable the greatest cross-platform and cross-browser compatibility, while simultaneously delivering rich, dynamic content.

Kinematics is a branch of biomechanics that deals with the description of motion. As part of the RIMAS project, two laboratory modules for reinforcing concepts related to linear and angular kinematics have been developed. The developed modules allow students to quantify human motion by acquiring coordinate data from digital video images. With the advances in digital video image technologies, it makes motion capture and digitizing process easier and become commonly used tool for the quantitative analysis of human movement. While students in an undergraduate biomechanics course are not expected to learn the details of biomechanical motion analysis, an introduction to elementary measurement techniques is useful. Exposure to measurement techniques provides students with an appreciation of how biomechanical data is obtained and introduces basic measurement concepts such as scaling. For example, when acquiring spatial measurements from the video images, a conversion must be made from the video image size to real life dimensions. For two-dimensional motion analysis, a recording of an object of known dimensions (e.g., a meter stick) placed in the plane of motion allows students to determine a conversion (scaling) factor for converting the length measured from the video image to a real life distance.

IMPLEMENTAITON OF LABORATORY MODULES: For the Linear Kinematics module, sagittal views of sprinting, running, and jogging motions were recorded from 10 university students. For the Angular Kinematics module, side views of giant swings were captured from several college level women gymnasts.

Preparation of Video Images: A digital camcorder (Model XL-1, Canon USA Inc., Lake Success, NY) was used to record the human motion. A NTSC digital video camcorder has an image capturing rate of 30 fps, which is not fast enough to capture fast action such as sprinting. However, when the movement was recorded in interlace mode, frames can be split to yield 60 images per second using digital video editing software. To minimize the time for digitizing, we decided to use 60 fps for sprinting and 30 fps for running and jogging. Captured video images were first transferred to a computer and saved as AVI files. The video recordings were edited using digital video editing software (Adobe Premier 6.0.) and then converted to series of JPEG files. To reduce file size, the color JPEG files were changed to grayscale using Adobe Photoshop 7.0. These JPEG images were then saved on a server connected to the Web.

LABORATORY PROCEDURES: On the main page of RIMAS, there are two menu titles -- one for biomechanics modules and the other for motor coordination modules. When the course Modules for Biomechanics is selected, another level of sub menu titles appears. Selecting either Linear Kinematics or Angular Kinematics will provide a brief description of the laboratory. When the user proceeds to the laboratory information window, he/she can download a student worksheet (either PDF or DOC files format) containing detailed information about the data collection, student activity, and an answer sheet.

Linear Kinematics: This module reinforces basic concepts in linear kinematics such as distance, speed, and acceleration. To begin a digitizing session, the student selects one of the image sets after downloading the student worksheet. Each set has three series of images showing side views of jogging, running, and sprinting motions, respectively, of the same individual (Figure 1). The student then digitizes the mid-hip (approximated as the center of gravity of the body), toe and heel locations of one stride for each locomotion condition. A linear scale is also digitized for scaling purposes. Using the coordinate data and the image identifications (i.e., frame numbers) at the instants of heel strike and toe off, and the time elapsed between consecutive images (1/30 s for jogging and running; 1/60 s for sprinting), the student computes selected stride cycle characteristics such as stride length, stride frequency, support and recovery times, and average running speed. Utilizing the plotting feature of this module, the student enters the results and the RIAMS plots different parameters against the locomotion mode. The RIMAS computes the horizontal velocity of the mid-hip (an instantaneous quantity) using the central difference method (Wood, 1982). On the answer sheet, the student (a) compares the average speed over a stride with the horizontal velocity of the mid-hip and (b) discusses the effect of running speed on different stride cycle characteristics.

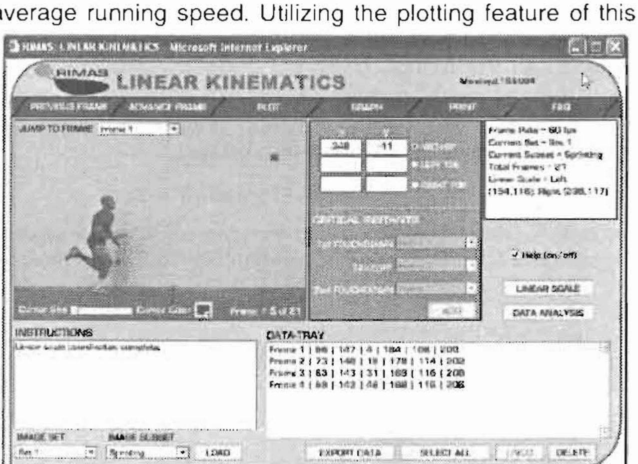

Figure 1: Digitizing of the Linear Kinematics module.

Angular Kinematics: This module aims to reinforce basic concepts in angular kinematics such as absolute and relative angles, angular velocity and angular acceleration. To begin a digitizing session, the student selects one of the image sets after downloading the student worksheet. Each image set provides side view of a gymnast performing one complete revolution of a forward giant swing. On each image, the student digitizes the near shoulder, hip, and knee (Figure 2). Once the digitizing is completed, the RIMAS smoothes the raw coordinates using high-order polynomials, compute the angular locations (angle from the positive x-axis in the counter-clockwise direction) of the truck and thigh, hip angles, angular velocities and accelerations of the trunk for all but a few frames at the beginning of the giant swing and output the data to the Output Window. The student computes different parameters for the first few frames using the raw coordinates.

Using the angular location data the student will compute the hip angle (a relative angle). The students then use the angular location, the time elapsed between consecutive images (1/30 sec), and the central difference method (Wood, 1982) to compute the angular velocities and accelerations of the trunk. In addition, the students calculate the maximum linear velocity of the hip using the largest angular velocity of the trunk and hand-hip distance. Based on the graph of the trunk angular velocity data, the student discusses the role of gravity in the changes in angular velocity throughout a giant swing.

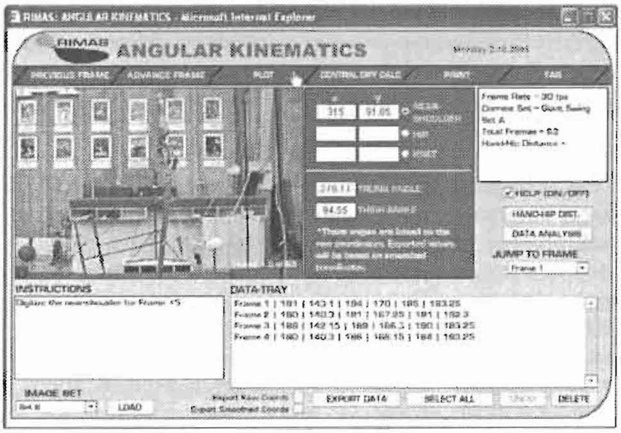

Figure 2: Digitizing window of the Angular Kinematics module.

EVALUATION: To improve and evaluate the effectiveness of the two kinematics modules, we invited members of the Advisory Panel of the RIMAS project to evaluate a beta version of each module. They were asked to complete an evaluation form [rating: 1 (poor) to 5 (excellent)] for each module they examined (Table 1). The beta-testing was also conducted in a Biomechanics course offered at the University of Florida in the fall semester, 2003. Students completed an evaluation questionnaire after completing each module (Table 2). Panelists and students also provided written comments and suggestions. The ratings from the panelists were generally higher than the ratings given by students. Ratings and written comments were helpful in improving the overall quality of these two modules. The results of beta-testing suggest that the two modules have the potential to supplement classroom lectures in biomechanics and facilitate the learning of kinematic concepts.

REFERENCE:

Wood, G.A. (1982). Data smoothing and differentiation procedures in biomechanics. In R.L. Terjung (Ed.), Exercise and Sport Sciences Reviews (pp. 308-362). The Franklin Institute Press.

Table 1 Summary of evaluation by advisory panelists.

	Questions	LK (n = 9)	AK (n = 7)
Structure & Contents	1. Structure is clear, intuitive, and easy to understand.	4.2	4.3
	2. Consistent graphics help with navigation.	5.0	4.0
	3. Links are accurately described and operate efficiently.	4.6	3.6
	4. Main path and button are clear and functional for further navigation.	4.2	4.0
	5. The site provides user-friendly help & support.	4.8	4.6
	6. Connections and page loading are fast for next step.	5.0	4.3
	7. Web pages are displayed correctly.	4.4	4.6
	8. Text information and instructions are easy to read.	4.6	4.3
	9. Downloadable files are easy & fast to download.	4.8	4.3
	10. Design is clean and uncluttered.	5.0	4.3
	11. Structure is clear, intuitive, and easy to understand.	4.5	4.3
	12. Consistent design/style gives the site coherence.	4.5	4.2
	13. The site creates good first impression.	5.0	4.0
	14. Is the site beneficial in demonstrating concepts related to kinematics?	4.2	4.2
	15.You can easily find out more about the author and site related additional information.	4.0	4.3
	16. Content is unique, and useful.	5.0	4.5
	17. Information is appropriate for the intended audience.	5.0	4.0
	18. information supports or enhances the curriculum.	4.8	4.0
	19. The site provided an appreciation of how video motion analysis is done.	4.5	4.0
Learning Process	1. The learner processes include higher order of thinking: Challenges learners think, discuss, compare, etc.	4.8	4.6
	2. Interactive instruction increases the educational value.	4.8	5.0
	3. Process engages the learners.	4.6	5.0
	4. The digitizing took a reasonable amount of time.	4.5	4.0

Table 2 Summary of evaluation by undergraduate students.

Questions	Rating (5 – 1:high – low)	LK(N=45)	AK(N=12)
1. Rate the overall quality of the RIMAS site.	Exceptionally high/Low	3.8	3.8
2. Rate the overall effectiveness of the site.	Exceptionally high/Low	3.5	3.7
3. How accessible was the site?	Very/Not Accessible	4.1	4.3
4. The site provided an appreciation of how scientific experiments are done.	To a Great Extent/Not at all	3.9	3.9
5. The amount of time to complete this module is adequate.	Strongly Agree/Disagree	3.2	3.3
6. The worksheet is adequate for providing concepts and instructions.	Strongly Agree/Disagree	3.2	3.0
7. Should there be more/fewer laboratories of this type in this course?	Many More/Fewer	3.2	3.7
8. Was the site beneficial in demonstrating concepts related to Reaction Time?	Very/Not Beneficial	3.7	3.3

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