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Work in Progress: Remote Laboratory Delivery with an At-Home Biomechanical Kinematic Data Acquisition Method

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Remote Laboratory Delivery with an At-Home Biomechanical Kinematic Data Acquisition Method (WIP)

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Abstract

Under the remote learning mode due to COVID-19, educational laboratory modules lacking the active data acquisition step tend to lose students' engagement and diminish their eagerness to explore further knowledge. Such shortcomings are more profound in practical fields of study, such as Biomechanics. The goal of this paper is to present a remote laboratory delivery and evaluation method where students can apply principles of kinematic and kinetic biomechanical analysis on their own body motions with a computer vision algorithm to interactively solve a motion analysis problem.

In this preliminary study, students were given the freedom to choose a specific body motion to be captured and analyzed, such as elbow, knee, wrist, and neck joint movements. Motion specifications included determination of the motion type, and also the starting and ending angular or linear positions. Readily available labels were utilized as passive joint markers. Students were then instructed to video record their joint motions using their laptop cameras. A custom video tracking algorithm specifically designed to track spatial locations was then employed to capture relative positions of the recorded motions. Laboratory instructions asked the students to perform kinematic calculations on the algorithm's generated positional data to determine joint velocities and accelerations, and then perform kinetic analyses to estimate the associated muscle forces. Laboratory requirements were concluded with a reflection prompt to evaluate the activity's workload and effort perceived by the students. These activities were delivered twice in two different academic terms. Samples of the produced kinematic data using our methods were verified in comparison with a standard physical motion capture system, where similar joint motion descriptive results were observed.

Results show that the completion rate of laboratory requirements was 97% in the first term of delivery, and 100% in the second term, as supported by the full technical reports submissions that included critical data analysis and reflections of the laboratory experience. Student reflections were very positive and expressed how the lab activity was interesting as it kept a high level of engagement and provided a way to make connections between practice and theory. In conclusion, the proposed approach may improve the students' laboratory experience in learning biomechanics through a motion analysis scenario, and allow them to remotely be fully engaged, active, and passionate learners.

Introduction

COVID-19 still challenges engineering colleges in delivering practical hands-on laboratory exercises in the present pandemic environment due to lack of the physical experience with laboratory equipment. Educators tend to record experimental laboratory data and provide instruction for their students on how to remotely perform data analysis and write lab reports in an online or hybrid course delivery modes [1]. In the study of biomechanics, kinematics is a one of its subfields that aims to describe body segments movements, while kinetics is another subfield that aims to study the forces and moments causing these body movements. Kinematics and kinetics laboratories aim to introduce the profession of research in biomechanics to Biomedical students, as they perform qualitative analyses of human movements and attempt to find clues of the factors affecting a certain motion that can cause injuries of performance degradation. Usually, such labs require existence of sophisticated and expensive three-dimensional motion tracking systems and combine motion and anthropometric data to perform informative analysis [2,3]. Few low-cost simpler solutions have been found the literature that enabled two-dimensional analysis of human motion. However, these solutions widely vary in their performance and computational accuracy [4,5]. In addition, these studies did not focus on the educational benefits of these alternatives.

It has been proven that active learning methods, across all STEM disciplines, is necessary to improve content and concepts retention, improve level of students' achievement, and ultimately, courses success [6,7]. Yet, such active learning techniques were challenged with remote materials delivery. Therefore, a need exists for a new tool to allow our students experience the learning process in an active and involved manner. In a prior report, the author introduced a remote biomechanical data acquisition tool to help achieve the active learning goals [8]. The study aimed to introduce a human motion capturing tool to engineering educators to estimate kinematic parameters in an at-home setting. Yet, it was not validated nor compared with the gold standard (3D motion tracking) and was applied only on one online class. In the current study, a refined motion analysis laboratory module is described, and the results of the module's application on another class; delivered in a hybrid mode, is presented. In addition, preliminary validation evidences are showing adequate relative accuracy of the captured kinematic data.

Methods

The proposed biomechanics laboratory module is based on video tracking predefined points that marks the moving body segment. The module prepares the students with introductory and background materials, and then asks the students to select a joint movement of their own choice (elbow, knee, neck …etc.). They are then guided to place two white labels (as markers) on the two ends of the body segment under consideration; example student's elbow joint markings are shown in figure 1. Some students found that placing a black dot in the middle of the white label helps the algorithm better track the markers. Students are then required to do the joint motion while recording that motion using their laptops' cameras for about 30 seconds.

A MATLAB script (MATLAB R2021b, MathWorks, Inc., Natick, MA, USA) provided by the instructor takes the recorded video as an input and provides an array with the coordinates of the two tracked points along the whole video duration. The algorithm required an interactive user determination of the initial

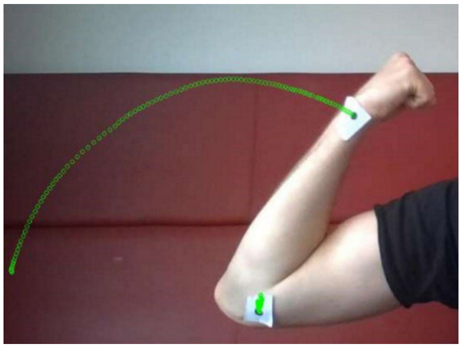

Figure 1. Student captured image showing the markers setup and experimentation with the video tracking algorithm on the elbow joint flexion-extension motion.

joint markers' positions. Video tracking was based on the Kanade-Lucas-Tomasi point tracking algorithm [9]. Accuracy of the tracking algorithm was tested in comparison with a motion tracking system (Smart DX, BTS Bioengineering, Italy) in which the same subject performed the same exercise while capturing the motion using the introduced algorithm and the commercial tracking system software.

Students would then employ the resultant coordinates in MATLAB and apply geometrical transformations to calculate the angular displacement of the joint motion (based on the tracked points in the cartesian coordinate system), then apply gradient operations to calculate angular velocity and acceleration. Using equilibrium equations, students were required to estimate muscle forces and moments, and from there, they could derive interpretations on their own estimated body motion parameters. All calculations, labeled plots, and conclusions, were submitted in a detailed lab report. The report concluded with a student's reflection statement, in which student were required to indicate which biomechanical principles were better understood as applied in this lab, what was the most enjoyable or tedious parts in the lab, and the lab workload and effort as perceived by the students. The lab was carried out in groups of 2-3 students to allow for collaborative constructive teamwork towards completion of a common activity. All students in the cohort were required to capture their individually chosen joint motions, but each group was required to agree on common conclusions and the reflections to be included in the lab report. All students' questions, and directions were all carried out either remotely or in a hybrid mode, according to the carried class mode.

Results

To ensure the proposed acquisition method provides meaningful and valid kinematic data, the custom video tracking algorithm was compared with a commercial motion capture system for a sample student's work; an example comparison in shown in figure 2 for the elbow flexion-extension motion depicted in figure 1. The elbow joint's angular motion was calculated and plotted using both systems, in which, a comparable elbow range of motion was noted (107^0 using the commercial system data and 113^0 using the custom algorithm). Additionally, the measured time to complete one cycle was comparable (2.65 and 2.85 seconds, for the commercial and custom systems, respectively).

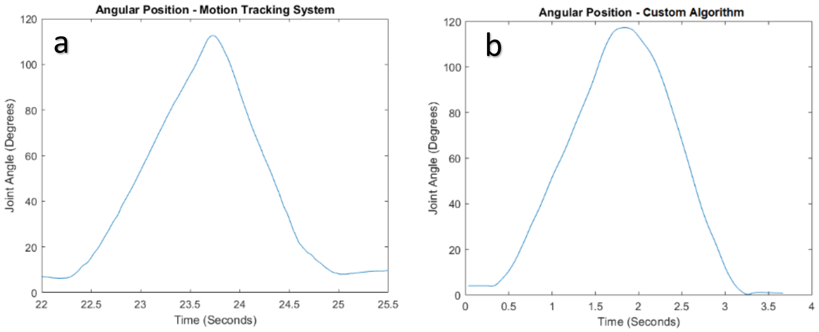

Figure 2. a) Angular displacement of an elbow joint flexion-extension cycle using the commercial 3D tracking system. b) Student's calculated angular displacement of the same elbow joint flexion-extension cycle using the custom 2D video tracking algorithm.

The remote lab module was applied in two terms. The first applied term was spring 2020 in an online class of 32 junior Biomedical engineering students, in which 31 out of 32 students

(97%) successfully completed all laboratory requirements and report submission (one student had low-resolution laptop webcam, was graded by showing understanding of lab steps). In the second term; spring 2021, a hybrid class of 29 junior Biomedical engineering students (15 in-person and 14 online students) completed all video tracking steps and successfully produced kinematic plots (100%).

Some of the student reflections were very positive of this lab module; example comments: "The lab activity makes me feel more aware about which muscles are controlling each movement" and "The most enjoyable part of this experiment was using the tracker to see how body segment moved". Out of excitement and motivation, some students applied video tracking on different body motions other than required in the lab; they expressed it was interesting to see how fast their body segments can move.

Conclusions and Future work

A two-dimensional video motion tracking algorithm was reported, and its relative accuracy was demonstrated compared to a commercial system. Deployment of such algorithm in a remote laboratory module in biomechanics was found to be feasible and adequate to many remote learners. Preliminary results showed successful student conduction of the experiments with positive indications of high engagement. The proposed laboratory module may improve the active learning experience of remote biomechanics students. However, the study did not include quantifiable student engagement nor assessment to identify success metrics. This is considered the next step of this study; an IRB for such work is under examination by the hosting institution.

Future applications of the module will include as survey questions scored according to Likert scale, so that statistical and graphical analysis can be performed. Students' reflections will be more focused on the perceived affective, behavioral, and cognitive features of the experience. It is also possible to have a control group to compare the student experiences with the motion capture system against the proposed method's experiences. The take-home message is that the presented module allows students to capture their own kinematic data for the joint motion of their choice in at at-home, hybrid, or in-class setting to better achieve the learning goals of biomechanical courses without necessitating the use of a sophisticated motion tracking system.

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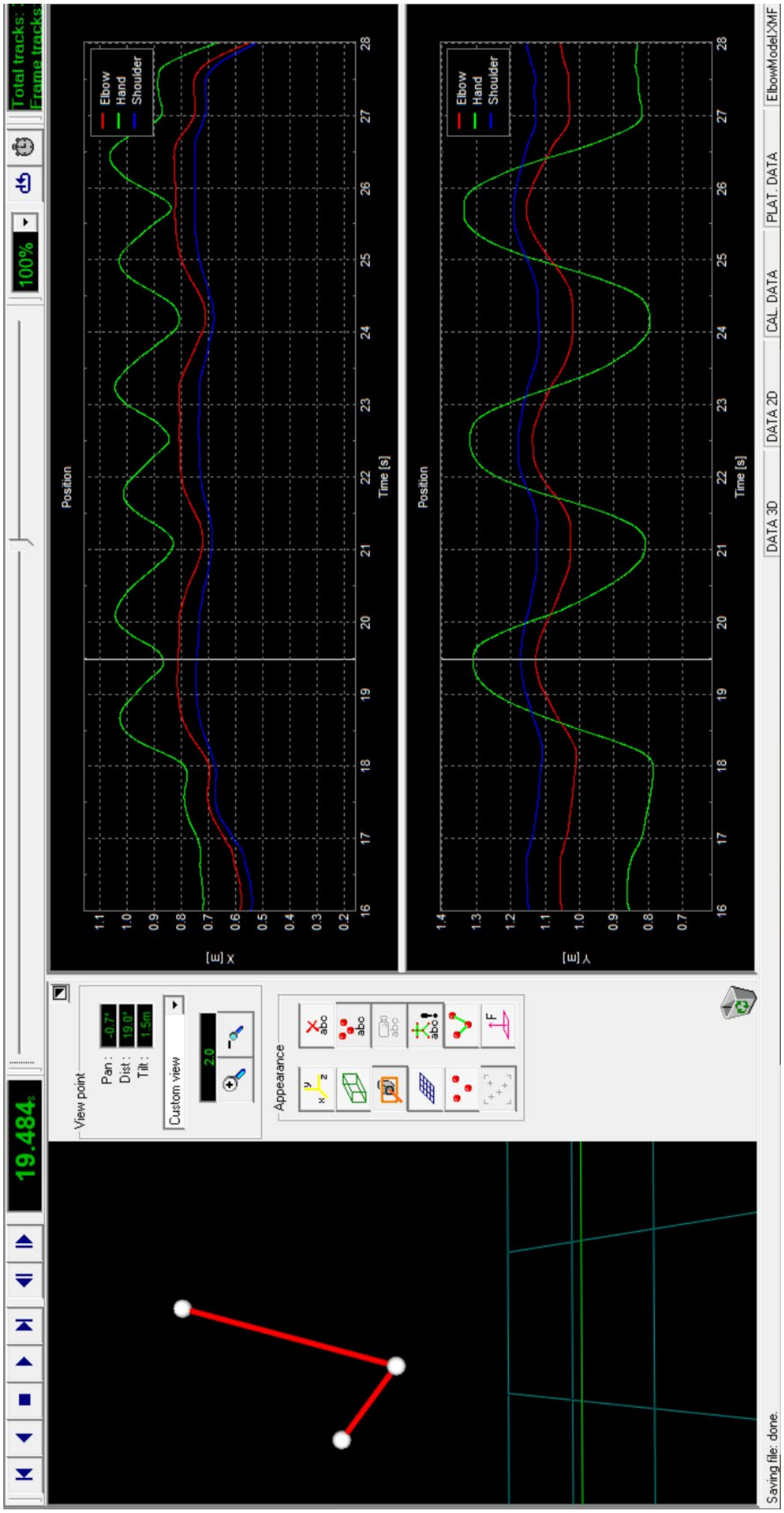
Appendix A: Elbow joint model within the commercial motion tracking system.



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