Work in Progress:Developing an integrated motion capture and video recording for pediatric biomechanical studies

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Dr. Habibi is an assistant professor in the Department of Integrated Engineering at the Minnesota State University-Mankato. He received his undergraduate and graduate degrees in Electrical Engineering. Following his postdoctoral appointments at the University of Wisconsin-Milwaukee, he joined the Iron Range Engineering (IRE) Program in August 2011. The IRE is an innovative, 100% project-based, upper division engineering program located in Virginia-Minnesota which promotes learning in the context of engineering projects, professionalism and reflection (metacognition). His research in the area of engineering education is focused on project-based learning, design and innovation, professionalism and self-directed learning.

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1. Project Overview

A kinematic understanding of gait has numerous applications in biomechanics, such as developing biometrics for gait pathologies and studying neuromuscular disorders[1,2,3]. Motion capture (mocap) and video recording from multiple perspectives have been used extensively to study, evaluate and develop effective treatments for patients with movement disorders. The integration of mocap and video recording provides valuable information that cannot be seen by eyes and significantly makes a difference in treatment methods. A commonly used method for mocap involves attaching reflective markers to the patient's muscles, and then using an array of infrared cameras to record the movement of muscles [4]. In this method, mocap and video recording are simultaneously performed and synchronized by a controller. Current data collection systems, when used for pediatric applications, carry on some problems such as adhering markers onto delicate skin of infants, high computer hardware requirements, parental concern, and high costs (up-front and maintenance).

The main objectives of this project are to develop a low-cost biomechanics data collection system suitable for pediatric biomechanics research. The entire system consists of three parts: video recording, markerless mocap, and electromyography (EMG) data collection. Three students and one faculty mentor from the Iron Range Engineering, an engineering program at the Minnesota State University- Mankato, developed the idea and completed the project for the Pediatric Neuromotor Laboratory at the University of Wisconsin-Milwaukee. Scoping the project showed that it would be unreasonable for the team of three students to develop entire system in one semester, so a three phase, multi-semester development process was planned for the project. Phases I, II, and III correspond with the video capture, mocap, and analog data collection components of the project, respectively.

The Phase I of the project was to develop a video recording and analysis component that is capable of recording from multiple video input devices simultaneously and also playback all the recorded video frame by frame in a synchronized manner. The objective for the Phase II is to create a markerless mocap system integrated with Phase I. The Phase II is meant to address current problems associated with using marker-based mocap with infants. The proposed solutions involve using multiple Kinects to record motion data and a graphical user interface (GUI) that enables the user to interact with the system. The GUI also synchronizes multiple video recordings and integrates them with the mocap data. The goal for the Phase III is to assimilate an EMG system with the Phase I and II. The Phase I was completed during the fall semester of 2012.

2. Iron Range Engineering Program

The Iron Range Engineering (IRE) program is an innovative engineering education model and a project-based program, where students learn and practice engineering in the context of their engineering projects [5,6,7]. Instead of attending in lecture-based classes, the IRE students select most of their technical competencies based on their team projects and use the projects to facilitate their learning. Studies have showed that this type of learning is more effective than traditional methods [8,9].

The IRE program was established in 2010 as a result of collaboration between two institutions (Itasca Community College and Minnesota State University – Mankato). The program promotes project-based, self-directed learning, and practicing engineering professionalism. Most of the IRE projects are industry-sponsored projects; however the students are encouraged to develop their own project ideas as well. The students form a team at the beginning of each semester and learn professionalism, design and technical skills in the context of their projects.

The IRE program is an upper-division program in which the students are graduates of local community colleges where they completed their freshman and sophomore years. They complete their junior and senior years at IRE. The curriculum consists of 60 credits, including 32 technical, 12 design, and 16 professionalism credits. After completing these 60 credits, the students graduate with a Bachelor of Science in engineering from Minnesota State University, Mankato. If they complete 12 out of 32 technical credits in a specific engineering discipline (i.e. electrical, mechanical, biomedical, etc.) they earn an emphasis in that discipline.

3. Project Approach

3.1 Design process

The team followed a generic engineering design process to complete this project. The process was consisted of: Scoping, Background Survey, Options Selections, Execution, Verification & Validation, and Delivery. Additionally, other design components such as patent search, engineering standards, and economic analysis were incorporated into the project to develop a more complete understanding of the different impacts that the project may have. Final deliverables for this project were all the codes compiled as executable files, a user manual, and a series of tutorial videos.

3.2 Weekly learning and design reviews

Once a week, the team and mentor spent four hour of Learning Review (LR) and Design Review (DR). The objectives of the DR were to provide an update on the project and to receive feedback from the project mentor. The project progress and tasks were tracked at each DR. The objectives of the LR were to address topics related to the engineering professional development. At each LR, the team discussed teamwork skills, engineering ethics, engineering design process, and

contextualization.

3.3 Technical learning

Unlike traditional design courses, where technical learning (i.e. coursework) may not be related to the design project, the idea behind project-based learning is to facilitate learning using design projects. The team used this project to facilitate the learning of signal processing, image processing, statistics, digital logic, and C# programming. While each of these topics can be learned effectively under traditional models, using the project as a context for the learning provided the students an immediate application of the learning and motivation for the topic.

For example, programming can be a difficult topic to study independently (for students without prior experience) due to the vast amounts of syntax and unclear transfer of knowledge from classroom learning to engineering problem solving. Two students from the team who did not have any prior programming experience used the project to guide their learning in C# programming. Additionally, the project provided motivation for learning the syntax, since programming would be the medium for solving the engineering design problem. The students were able to learn the big ideas for developing applications first, and then cover the small details to improve their work (reverse of traditional teaching). The synergy between the design project and the technical learning was felt in other courses as well, e.g. image processing. Table 1 shows project-related competencies which each team member enrolled in.

Table 1. Project related competencies enrolled by each team member

Student A	Student B	Student C
Signal Processing	Image Processing	Signal Processing
Image Processing	Advanced Instrumentation	Image Processing
Intro to Biomed Research	Manufacturing Processes	Statistics
Bioinstrumentation		
Digital Logic		
Manufacturing Processes		

3.4 Task delegation/management

There were two types of project tasks that the team needed to complete: final deliverables and documentation. The team decided to delegate design activities to the individual team members based on their personal interests, strengths, and specialties. Even though tasks were delegated, most design activities became team efforts from the amount of collaboration between the members. The documentation was delegated to individual team members so that the act of documenting the design activities would not consume the time of the entire team (see table 2). The tasks were generated and tracked at each weekly DR. Also, new tasks and goals for the following week were generated and delegated during each DR.

Table 2. Documentation delegated to each team member

Student A	Student B	Student C
Background Survey	Scoping	Patent Search
Engineering Standard	Experiment Design	Options Document
Statistical Analysis	Statistical Analysis	Economic Analysis
Experiment Design	Project Management	Sustainability Analysis
Design Improvement	Contextualization	Reliability Analysis

3.5 Entrepreneurship and new ideas

While the scope, outcomes, and deliverables for the project were completely defined, this project facilitated many discussions for the team regarding the entrepreneurial implications of markerless mocap systems. One of the topics during the weekly LR was to consider the applications and implications for the learning achieved from completing this project. For example, potential medical applications for a low-cost markerless mocap system include biofeedback for in-house physical therapy, and fall prediction in nursing homes. The team also considered non-medical applications for this project such as household automation, ergonomics, and personalized clothing.

4. Conclusions

The Phase I of the project, which included recording from multiple video inputs simultaneously and also playback all the recorded video frame by frame in a synchronized manner, was completed in fall 2012 using multiple webcams and C# development tools. The next step is to develop an inexpensive, markerless, highly accurate mocap system using multiple Kinects.

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