A COMPARISON OF TWO COMMERCIALLY AVAILABLE MOTION CAPTURE SYSTEMS FOR GAIT ANALYSIS: HIGH-END VS LOW-COST

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INTRODUCTION

In 1999 Richards [1] compared the accuracy of commercially available motion capture systems commonly used in biomechanics. Richards identified that in static tests the optical motion capture systems generally produced RMS errors of less than 1.0 mm. During dynamic tests, the RMS error increased to up to 4.2 mm in some systems.

In the last 12 years motion capture systems have continued to evolve and now include high-resolution CCD or CMOS image sensors, wireless communication, and high full frame sampling frequencies. In addition to hardware advances, there have also been a number of advances in software, which includes improved calibration and tracking algorithms, real time data streaming, and the introduction of the c3d standard. These advances have allowed the system manufactures to maintain a high retail price in the name of advancement. In areas such as gait analysis and ergonomics many of the advanced features such as high resolution image sensors and high sampling frequencies are not required due to the nature of the task often investigated. Recently Natural Point introduced low cost cameras, which on face value appear to be suitable as at very least a high quality teaching tool in biomechanics and possibly even a research tool when coupled with the correct calibration and tracking software.

The aim of the study was therefore to compare both the linear accuracy and quality of angular kinematics from a typical high end motion capture system and a low cost system during a simple task.

METHODS

We investigated 1) the linear accuracy and 2) the quality of walking gait data from a low cost (AU$ 15,000 at the time of purchase including software) OptiTrack system (Natural Point, OR, USA) and high end (approx. AU$250,000 at the time of purchase) Vicon system (Vicon, Oxford, UK). In both studies, data were sampled simultaneously from a 12 camera Vicon MX system and a 12 camera OptiTrack system (FLEX:V100R2). All data were collected at ErgoLab, University of South Australia. The cameras were positioned in pairs of one OptiTrack and one Vicon camera. The lens-to-lens distance was measured using a 3m Faro Fusion Arm (FARO Europe GmbH & Co. KG). The mean lens-to-lens distance was 0.33 m (SD = 0.17 m). Both systems were calibrated the principal author. The calibrated

volume was approximately 2.5 m x 1.5 m x 1.5 m. Vicon data were tracked in Nexus 1.6.1 and OptiTrack data were tracked in AMASS 1.0 (C-Motion, Inc. USA). Both systems sampled data at 100 Hz. After tracking, all data were exported to c3d format and imported into Visual3D (C-Motion, Inc. USA) where all signal processing and calculations were performed. For both experiments data were filtered with a 4th order low-pass Butterworth filter with a cut off frequency of 6 Hz.

Experiment 1 – Linear Accuracy

Linear accuracy was assessed in a static test and two different dynamic tests. We tested the linear accuracy of both systems using a standard reference frame (Vicon 5-marker T frame). The exact dimensions of the frame were measured using a Faro Arm, with a spatial resolution of ± 0.104 mm. In this experiment, only two markers on the reference frame were used. The measured distance and reference dimension to which both systems were compared was 0.120 m. In the static test the reference frame was positioned on the floor, centrally in the capture volume. Three, five second trials were collected. Dynamic linear accuracy was tested using the same reference frame. The reference frame was walked through the capture volume held as close to the lower boundary of the calibration volume as possible and in the middle of the calibration volume at approximately hip height. Three trials at each height were collected. From the data the absolute magnitude of the distance between the two markers was calculated and the absolute percentage error.

Experiment 2 – Quality of Gait Data

Gait data from a single participant was collected. The participant walked at a self-selected pace through the lab. Three dynamic trials were collected. Prior to this, a static posture calibration file was collected to define the position and orientation in space of the body segments [2]. The segments of the lower limbs and pelvis were modeled in six-degrees of freedom. From the data collected joint kinematics were calculated for the ankle, knee, hip, and pelvis. The analysis focused on joint kinematics in the sagittal, coronal and transverse planes at quartiles of stance phase.

RESULTS AND DISCUSSION

Experiment 1:

The linear accuracy tested identified a maximum absolute percentage error of 0.84% for the dynamic test in the mid

volume of the OptiTrack system. In all of the conditions, the OptiTrack system produced higher errors than the Vicon system (Figure 1). While the Vicon system does appear to be able to have higher linear accuracy than the OptiTrack system, it is also clear that both systems perform exceptionally in this experiment as no percentage absolute errors were found to exceed 1%. These tests suggest that in the absence of rotation the low cost OptiTrack system is comparable to the high end Vicon system.
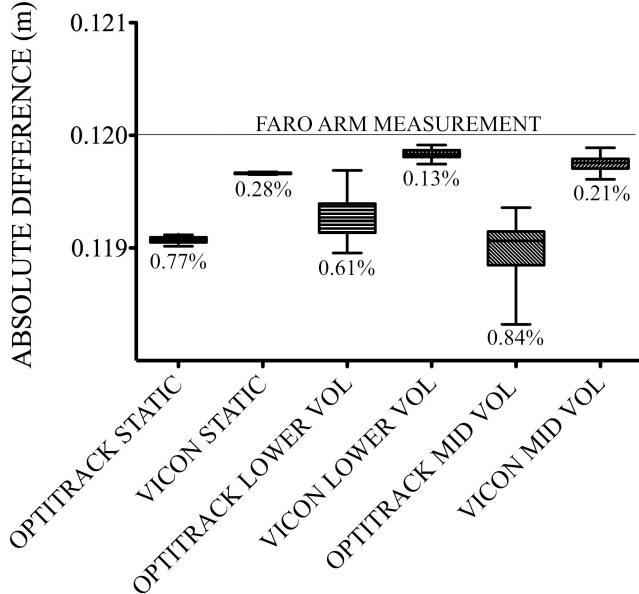

Figure 1: Linear accuracy during the static and dynamic tests expressed as an absolute measure (95% Confidence intervals) and absolute percentage error.

Experiment 2:
The findings of the gait study identified that largest relative difference between the two systems occurred in the transverse plane knee rotation at 75% of stance phase (4.2°). No other comparisons identified a relative difference greater than 4°. In fact only 5 of the 60 points of data extracted identified a relative difference of greater than 3° (Figure 2). Four of these points were transverse plane knee rotation and the remaining point was transverse plane hip rotation, both of which are known to be highly sensitive to static marker placement used to define the anatomical frame and soft tissue movement artifact [3]. Further analysis of the data identified that subtle difference were evident in both the angular acceleration data and linear acceleration data of the markers. The differences in accelerations suggest small differences in the onboard processing of the coordinate data at the cameras. While it is possible to describe the difference between the two systems it is not possible based on the data available to establish which system, if either is most accurate. It is likely that neither system is absolutely correct.

CONCLUSIONS
Low cost systems such as the OptiTrack system have obvious limitations, which include relatively small capture volumes due to lower strobe strength, lower sampling frequencies (max 100 Hz), and less streamlined software.

Despite these limitations, the findings of this study suggest that these systems provide a genuine alternative to high-end systems when used in areas such as gait analysis and ergonomics. The findings of this study suggest that in both linear and angular tests a low cost solution can be deemed comparable to its high-end competitor.
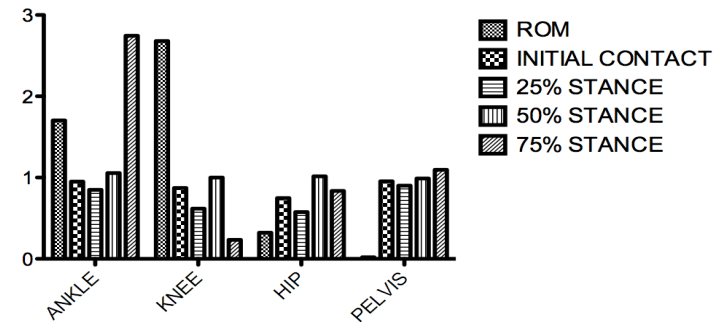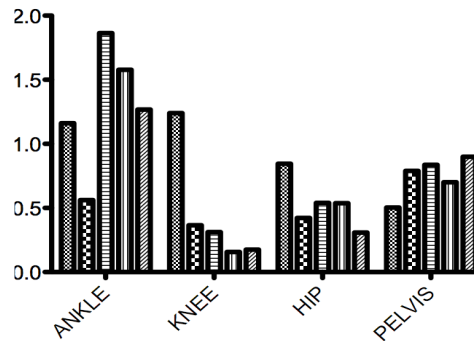
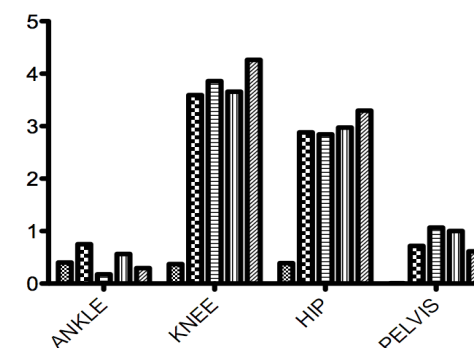**Figure 2**: Absolute difference (degrees) between the two systems in the sagittal, coronal and transverse planes.

REFERENCES
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