VIDEO-BASED MARKER-LESS TRACKING SYSTEM IN GAIT ANALYSIS

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An alternative to the 3D motion marker-based optical camera capture is the Star Tracker 3D, a marker-less video-based tracking system. The aim of our study is to investigate the efficacy of the Star Tracker 3D. A series of gait analysis tests were carried out on ten subjects with a marker and marker-less tracking system simultaneously. The study suggests potential application in gait analysis in the academic classrooms and clinical settings where observations of anatomical motions can provide meaningful feedback.

KEY WORDS: Markerless, motion-capture, gait, three-dimension, biomechanics

INTRODUCTION: Gait analysis is an effective tool in the clinical decision making process for improving treatment outcome in an individual particularly with respect to lower limb injuries (Engsberg et al., 2007). Such analyses typically require relevant information such as foot pronation, tibia rotation and multiple-joints coordination to be augmented to the user simultaneously with real scenes captured by imaging equipment. This is often captured using high-speed motion capture systems. However, existing motion capture systems are arguably expensive and bulky, requiring practically at least 6 precision proprietary cameras and these are mainly installed in specialised institutions. Consequently, a large proportion of the population seeking medical consultations for such injuries at polyclinics and neighbourhood doctors will not have immediate direct access to the equipment. The alternative to this would be to develop a markerless tracking system that is to be not only precise and accurate, but also less expensive and user friendly. Recently, Republic Polytechnic have developed a video-based marker-less tracking system (Star Tracker 3D) 2 camera system that aims to provide intuitive and observable results for doctors allowing them to remotely diagnose for the convenience of mainstream patients without the need to use high-speed motion capture systems. However, this system has not been rigorously evaluated. As such, the aim of this study was to investigate the efficacy of a video based marker-less Star Tracker 3D system. It was hypothesised that data obtained from Star Tracker 3D would be significantly different from an existing motion capture system.

METHODS: Approval was received from the Republic Polytechnic human research ethics committee with reference to the involvement of human subjects in this project. A total of ten male subjects aged nineteen to twenty six participated in this study. On the actual day of testing, all subjects were healthy and not suffering from any lower limb musculoskeletal injuries. Both written and informed consent were provided to and obtained from all subjects prior to data collection.

Eight Eagle-4 MAC high-speed optical motion cameras (Motion Analysis Corp., Santa Rosa, CA) were placed around the motorized treadmill (H/P Cosmos Gaitway II S, Germany). Two Point Grey cameras (GS2-FW-14S5C, Canada) from the Star Tracker 3D system were also placed at pre-selected positions ensuring both cameras focusing on the same point in 3D space. The sampling frequencies for both high-speed and Point Grey cameras were set at 100 Hz and 25 Hz respectively.

For the motion capture system, retro-reflective markers were placed on the pelvis, shank and foot to track their positions in space (Dierks and Davis 2007). All subjects were instructed to walk on the treadmill at their self-selected speed for approximately 8 minutes (Lavcanska et al., 2005). Kinematic data were collected for final 30 seconds during the 8th minute and data collected from the first three consecutive complete strides during the 8th minute were used for final analysis. All data collected were normalized to 100% of the foot contact.

Kinematic data gathered from both high-speed motion capture and Star Tracker 3D systems were (a) translational data about the x-, y- and z-axes where each axis is anterior(+)/posterior (-), lateral/medial and superior(+)/inferior(-) (axial) respectively and (b) angular data; also about x-, y- and z-axes where each axis is flexion(+)/extension(-), abduction(+)/adduction(-) and internal(+)/external(-) rotation respectively. For this study, translational data were used to calculate angular data as highlighted in Chang et al. (2008). All kinematic data were filtered using the Butterworth low-pass filter with a cut-off frequency of 6Hz. The processing pipeline used in the Star Tracker 3D system was adapted from (Zhang et al., 2011). To decrease the processing time, the area for tracking for each segment is automated. Only the first frame is manually digitized.

RESULTS: Translational and angular data showed similar trends throughout the time history patterns between systems (Figures 1 and 2). Statistical analysis revealed no significant difference ($p>0.05$) in translational data (Table 1), but not for angular data ($p<0.05$) between the Star Tracker 3D System and high-speed motion capture systems for all segments and its respective anatomical references (Table 2).

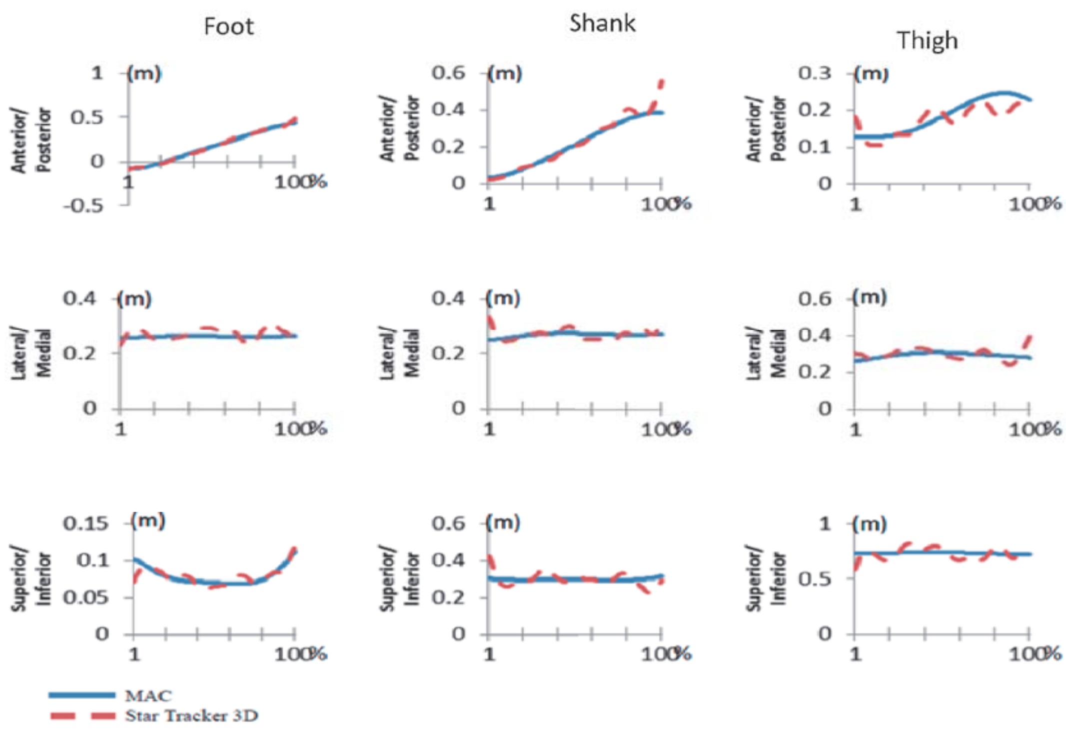

Figure 1. Time History Pattern of Translational Data between Star Tracker 3D and High-Speed MAC Motion Capture System

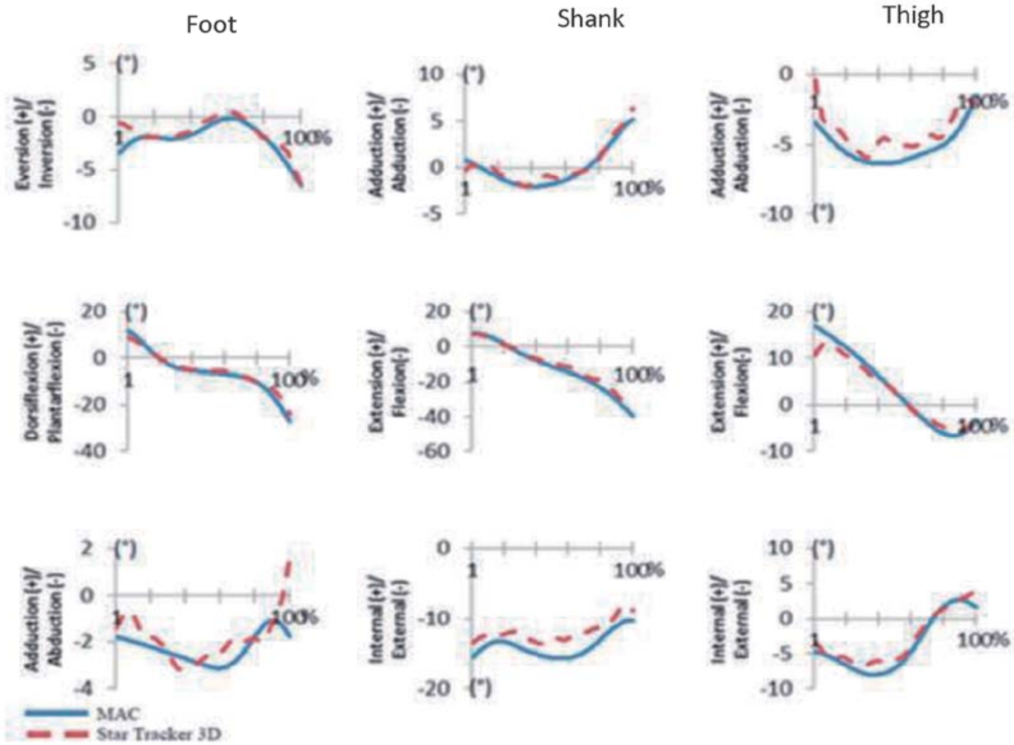

Figure 2. Time History Pattern of Angular Data between Star Tracker 3D and High-Sped MAC Motion Capture System

Table 1. Comparison of Translational Data between Star Tracker 3D and High-Speed Motion Capture Systems in the anterior/posterior (Ant/Post), Medial/Lateral (Med/Lat) and Axial directions for the Foot, Shank and Thigh segments. *(MD = Mean difference in measurement between the 2 systems, RMSE = root mean square error between measurements of the 2 systems, RC = range of confidence; RC = 2 X RMSE).*

	Foot			Shank			Thigh		
	Ant/ Post	Med/ Lat (cm)	Axial	Ant/ Post	Med/ Lat (cm)	Axial	Ant/ Post	Med/ Lat (cm)	Axial
MD	3.01	2.51	2.78	1.95	2.17	2.23	5.92	2.56	4.52
RMSE	0.98	0.68	0.79	0.29	0.39	0.45	0.75	0.28	1.12
RC	1.96	1.36	1.58	0.58	0.78	0.90	1.50	0.55	2.24
P value	0.31	0.23	0.34	0.10	0.23	0.09	0.58	0.53	0.45

Table 2. Comparison of Angular Data between Star tracker 3D and High-Speed Motion Capture Systems in terms of Flexion/Extension (Flex Ext), Adduction/Abduction (Add/Abd), Internal/External Rotation (Int/Ext), Plantar/Dorsi flexion (Plant/Dorsi) and Inversion/Eversion (Inv/Eve) for the Foot, Shank and Thigh segments. *(MD= Mean difference in measurement between the 2 systems, RMSE=root mean square error between measurements of the 2 systems, RC = range of confidence; RC = 2 X RMSE). Significant differences (p <0.05) are marked with an asterisk (*)*

	Foot (°)			Shank (°)			Thigh (°)		
	*Plant/ Dorsi	*Add/ Abd	*Inv/ Eve	*Flex/ Ext	*Add/ Abd	*Int/ Ext	*Flex/ Ext	*Add/ Abd	*Int/ Ext
MD	3.94	2.92	3.01	4.12	2.48	3.23	3.01	2.02	1.01
RMSE	0.81	1.01	0.88	1.07	0.88	1.58	0.51	1.07	0.36
RC	1.62	2.02	1.76	2.14	1.76	3.16	1.02	2.14	0.72
P value	0.03	0.01	0.01	0.04	0.01	0.01	0.03	0.04	0.02

DISCUSSION: The aim of this study was to investigate the efficacy of the Star Tracker 3D video-based marker-less system by comparing translation and angular data gathered between systems. It was hypothesised that data obtained from Star Tracker 3D would be significantly different to an existing high speed motion capture system. As highlighted in Figures 1 and 2, the time history pattern of both translational and angular data showed similar trends throughout the normalized time for all the three segments. This suggests that there may be feasible agreement between the two systems where no significant differences were observed in translational data (Table 1) between systems. Given that these translational findings rejected the hypothesis, the Star Tracker 3D System may be a feasible system to capture translational data.

Despite showing similar trends throughout the normalized time for all the three segments (Figure 2), statistical analysis revealed significant differences in angular data between the two systems (Table 2). Unlike translational data, angular data did not facilitate the rejection of the null hypothesis indicating that the Star Tracker 3D may not be as accurate as existing motion capture systems in terms of angular data capture. Considering that translational data was used to calculate angular data, one possible reason for this may be attributed to blur-motion when using the low resolution Point Grey cameras. This, according to Ting & Peng (2010), may inhibit the camera's ability to accurately pint-point the correct location of the specific features in 3D space. Another reason may be attributed to differences in sampling frequencies. When compared to high-speed cameras capturing data in excess of 50 Hz, the Point Grey cameras captured data at 25 Hz. Such lower sampling frequencies may have prevented the low resolution cameras from capturing as many data even when normalised to 100% time frame. Insufficient data points from the relatively fast moving markers may have been captured for a given period, rendering significant differences in angular computations as relevant information may not have been fully obtained. One way to overcome this may be to increase the number of cameras that have higher resolution sensors and with faster sampling rate when capturing angular data using the Star Tracker 3D system. As similar trends are observed, angular data may depict general segmental movements where accuracy is not required.

The study suggests feasible application of the Star Tracker 3D system for gait analysis in clinical settings and the academic classrooms where general observations of anatomical motions could provide meaningful feedback. For example, observing gait patterns between injured and non-injured patients without the need to use high-speed motion capture systems which are often expensive would provide practioners and educators the ability to immediately gather feedback on gait characteristics. When used in commercial footwear retail shops, the Star Tracker 3D system could supplement the current method of assessing foot morphology qualitatively by providing insights to pronation or supination of the foot as one walks which otherwise, in the past, would require the use of the more expensive and complex high-speed optical camera systems.

CONCLUSION

Similar time-history patterns for translational and angular data with insignificant differences in the translational data suggests that that the Star Tracker 3D System may be a feasible system in gait analysis in clinical settings and the academic classrooms where observations of anatomical motions provides meaningful feedback. When more detailed and accurate quantitative measurements are required marker-based higher speed optical camera systems should be used.

REFERENCES:

Dierks, T. A., & Davis, I. (2007). Discrete and continuous joint coupling relationships in uninjured recreational runners. *Clinical Biomechanics*, *22*(5), 581-591Engsberg, J. R., Tucker, C., Ounpuu, S., Wren, T. A., Sisto, S. A., & Kaufman, K. R. (2009). Gait and clinical movement analysis research priorities: 2007 Update from the research committee of the gait and clinical movement analysis society. *Gait & posture*, *29*(2), 169-171.

Lavcanska, V., Taylor, N. F., & Schache, A. G. (2005). Familiarization to treadmill running in young unimpaired adults. *Human movement science*, *24*(4), 544-557.

Ting-Fa, X., & Peng, Z. (2010). Object's translational speed measurement using motion blur information. *Measurement*, *43*(9), 1173-1179

Zhang, Z., Seah, H. S., Quah, C. K., Ong, A., & Jabbar, K. (2011). A multiple camera system with real-time volume reconstruction for articulated skeleton pose tracking. In *Advances in Multimedia Modeling* (pp. 182-192). Springer Berlin Heidelberg.