Estimating Anatomically Plausible Segment Orientations using a Kinect One Sensor

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Introduction: Marker-based motion tracking systems are the golden standard for human motion analysis, however such systems are expensive, non-portable and require long time subject preparation. The Kinect One sensor, being inexpensive, portable and markerless, appears as a reliable and valid alternative to the marker-based systems in several situations [1–3]. This sensor acquires depth image data and color camera data that are processed by a tracking algorithm to estimate the three-dimensional position of twenty-five anatomical joints in real-time [4]. Nevertheless, the internal orientations of each anatomical segment are poorly estimated. The main objective of this work is to study the effectiveness of vector orthogonalization methods to estimate the relative internal orientations of the anatomical body segments using the skeletal data acquired by a Kinect One sensor.

Materials and Methods: Twenty-eight healthy adults (25 ± 9 yrs old, 170 ± 9 cm height, 61 ± 9 kg weight, 13 women) performed 5 repetitions of ten different elementary movements: shoulder flexion/hyperextension, shoulder abduction/adduction, shoulder transversal abduction/adduction, shoulder medial/lateral rotation, elbow flexion, forearm pronation/supination, hip flexion/hyperextension, hip abduction/adduction, knee flexion and hip medial/lateral rotation. On each repetition, the subject started from an adapted pose of the anatomical reference position and finished on the same position it started with. Data was collected, simultaneously, using a marker-based system (Qualysis - 100 Hz) and a markerless system (Kinect One - 30 Hz). The biomechanical model used was composed by eleven anatomical segments: the head, the chest, the abdomen and both arms, forearms, thighs and legs. Six different vector orthogonalization methods (Householder, Eberly, Square Plate, Spherical and Projection Matrix) were used to estimate the relative orientations of the anatomical body segments from Kinect One sensor model [5]. Pearson's correlation coefficient was computed for kinematic variables of both systems.

Results: The results obtained show that the six techniques implemented estimated with good to very good correlation (0.58 – 0.93) the segment orientation around one axis of rotation while for the remaining axes the results are considerably worse (-0.37 – 0.46). Additionally, the performance of each technique varies according with the selected movement.

Discussion and Conclusions: Although vector orthogonalization techniques are capable to estimate plausible orientations, the results given the same movement shows significant differences, suggesting that not all vector orthogonalization techniques are appropriate for all movements. Finally, it is possible to conclude that Kinect One shows good results for some kinematic variables, nevertheless, it needs to improve the precision on the estimation of the joints' position and all body segments' orientation in order to obtain results similar to marker-based systems.

References:

1. Bonnechere B, Jansen B, Salvia P, Bouzahouene H, Omelina L, Moiseev F, et al. Validity and reliability of the Kinect within functional assessment activities : Comparison with standard stereophotogrammetry. 2014;39:593–8.
2. Clark R a, Bower KJ, Mentiplay BF, Paterson K, Pua Y-H. Concurrent validity of the Microsoft Kinect for assessment of spatiotemporal gait variables. J Biomech [Internet]. 2013 Oct 18 [cited 2014 Mar 31];46(15):2722–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24016679
3. Clark Yong-Hao Pua Cristino C Oliveira Kelly J Bower Shamala Thilarajah Rebekah McGaw Ksaniel Hasanki Benjamin F Mentiplay RA, Y-h P. Reliability and concurrent validity of the Microsoft Kinect V2 for assessment of standing balance and postural control. Gait Posture [Internet]. 2015; Available from: http://dx.doi.org/
4. Shotton BJ, Sharp T, Kipman A, Fitzgibbon A, Finocchio M, Blake A, et al. Real-Time Human Pose Recognition in Parts from Single Depth Images. 2011;
5. D.S. Lopes, M.T. Silva, and J.A. Ambrósio, Tangent vectors to a 3-D surface normal: A geometric tool to find orthogonal vectors based on the Householder transformation, Computer-Aided Design, 45(3): 683 - 694, 2013. DOI: 10.1016/j.cad.2012.11.003

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