Evaluation of joint angle accuracy using markerless silhouette-based tracking and hybrid tracking against traditional marker tracking – evaluation for specific joint movements

L. Becker, Ph. Russ

Introduction: Markerless tracking is seen as potential technology to make movement analysis simpler, quicker and better available. Previous methods of markerless tracking show a lack of accuracy for sports and medical applications [1,2,3,4]. Goal of this study was to evaluate accuracy of markerless and hybrid tracking of the new Simi Shape against traditional marker-based tracking.

Method: One subject has been recorded performing movements in all major joints and planes (22 movements). A commercial marker-based motion capture software (Simi Motion 3D, <0.1 mm mean failure) has been used to obtain 3D marker data. Joint angles have been computed using ISB standard conform joint axes.* Markerless silhouette-based joint angle data have been processed with a new markerless motion capture software (Simi Shape) as well as hybrid data by using different marker combinations to assist silhouette tracking. Both marker-based and markerless resp. hybrid data have been recorded at the same time using 8 cameras (0.3MP@100 Hz). For each movement recordings with 595 ± 129 frames have been made and joint angles have been compared using spearman correlation coefficient (data are not normally distributed) and standard deviation of angle difference.

* computed with the Simi Motion Inverse Kinematics module [5]

Results: Correlations have been defined to be very good when ≥0.9. Pure silhouette tracking shows problems when the silhouette appearance barely changes during segment rotation. This can also affect elbow angles as the elbow is performing a hyperextension instead of a flexion if the arm is strongly rotated in the shoulder joint and therefore, very high negative correlations occur. Also the pelvis segment is difficult to track because of its nearly rotationally symmetric shape and by that hip angles are affected. Moreover, the silhouette barely changes during foot eversion/inversion movements that consequently cannot be tracked accurately. Using hybrid tracking in Simi Shape, which means additional markers are taken into the computation to assist the silhouette tracking, with a total number of 15 markers all values are very good.

Table 1: Correlations and standard deviations of angle difference of markerless and hybrid data from Simi Shape vs. marker-based data from Simi Motion. Correlation coefficients ≥0.9 represented in green, ≥0.7 in yellow, <0.7 in red. First value shows the right body side, second value shows the left body side

		MARKERLESS		HYBRID		
joint	movement	correlation	SD of angle difference [°]	correlation	SD of angle difference [°]	used markers
hip	flexion/extension	0.86 / 0.91	14.5 / 18.6	1.00 / 0.99	2.0 / 3.2	3 pelvis
	abduction/adduction	0.97 / 0.98	5.4 / 2.8	0.99 / 0.99	1.9 / 2.0	3 pelvis
	rotation	0.93 / 0.93	10.4 / 6.6	0.96 / 0.97	2.6 / 4.0	3 pelvis, lat. knee
knee	flexion/extension	1.00 / 1.00	3.3 / 4.5	very good markerless tracking		
ankle	plantar/dorsal flexion	0.98 / 0.96	3.9 / 5.5	0.98 / 0.98	3.7 / 3.8	forefoot
	eversion/inversion	0.39 / 0.81	5.5 / 4.1	0.94 / 0.91	2.1 / 3.7	lat. ankle
	abduction/adduction	0.58 / 0.90	7.9 / 5.6	0.92 / 0.96	5.0 / 3.1	lat. and med. knee
shoulder	flexion/extension	1.00 / 1.00	7.4 / 14.4	good markerless tracking (high standard deviations of angle difference because of diff. defined shoulder joint centers)		
	abduction/adduction	0.88 / 0.78	9.9 / 13.3	0.93 / 0.95	7.6 / 5.6	lat. elbow, triceps
	rotation	0.90 / -0.10	14.5 / 24.6	0.99 / 1.00	1.6 / 3.1	triceps
elbow	flexion/extension	1.00/ -0.99	5.9 / 106.4	0.99 / 0.99	4.5 / 7.1	triceps

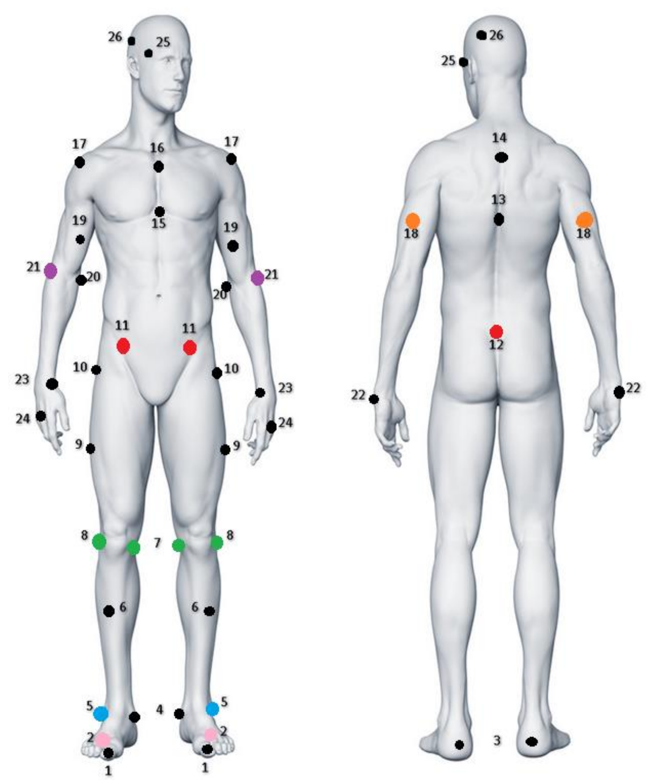

Figure 1 : Full body marker-based setup – Hybrid tracking markers highlighted

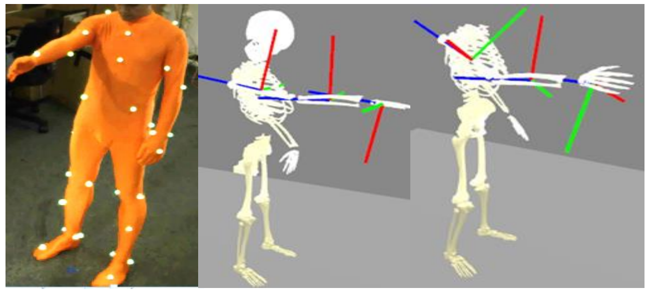

Figure 2: Camera image, marker based data, markerless data

Discussion: This study shows that markerless tracking of specific joint movements can achieve good results for most joint angles. However, to achieve very good results in all joint angles hybrid tracking with few additional markers/features to support silhouette tracking is necessary. This is especially important for segments where the silhouette barely changes during rotation. It has been shown which markers are needed for specific joint movements to improve results. By using a total of 15 markers in a hybrid setting instead of 37 for a full body marker based model, comparable full body inverse kinematic data can be obtained. In this study, only markers included in the marker based trial setup were tested. Different marker applications could be subject to further investigation.

References:

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