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

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simi reality motion systems

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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. In a previous study [5] hybrid marker setups for specific joint movements have been evaluated. In this study complex movements have been analyzed.

Method: Recordings of 12 different movements (biking, various kinds of jumping and running, jumping jack, kicks and box punches) have been made. 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 278 ± 229 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 [6]

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, foot movements (eversion/inversion and abduction/adduction) 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 19 markers all values are very good. Problems only occur for foot eversion/inversion and abduction/adduction movements if markerless and hybrid data are compared to marker-based data tracked in Simi Motion due to differently built knee models. Comparing markerless and hybrid data to full marker-based tracking in Shape without using silhouette correspondences (using the same human model) results are good. The mean value of correlation of eversion/inversion movements is good but not very good because many movements with only very small ranges of motion were performed.

Table 1: Correlations and standard deviations of angle difference of markerless and hybrid data from Simi Shape vs. marker-based data from Simi Motion. Data represent mean values and standard deviations over all movements as well as right and left body side. Correlation coefficients ≥0.9 represented in green, ≥0.7 represented in yellow, <0.7 represented in red

		MARKERLESS				HYBRID				
joint	movement	correlation		SD of angle difference [°]		correlation		SD of angle difference [°]		used markers
hip	flexion/extension	0.82 (±0.21)		6.4 (±2.9)		0.99 (±0.02)		1.7 (±0.8)		3 pelvis
	abduction/adduction	0.51 (±0.45)		4.6 (±1.5)		0.94 (±0.09)		1.2 (±0.7)		3 pelvis
	rotation	0.41 (±0.32)		9.2 (±3.8)		0.93 (±0.05)		1.6 (±0.8)		3 pelvis, lat. and med. knee
knee	flexion/extension	0.98 (±0.03)		2.6 (±1.1)		very good markerless tracking				
ankle	plantar/dorsal flexion	0.91 (±0.08)		5.3 (±2.9)		0.96 (±0.04)		2.4 (±1.0)		forefoot, heel
	eversion/inversion	0.26 (±0.42)	0.42 (±0.36)*	5.0 (±2.4)	5.0 (±2.3) *	0.38 (±0.33)	0.78 (±0.24)*	3.6 (±1.6)	2.3 (±0.9) *	lat. and med. ankle
	abduction/adduction	0.34 (±0.40)	0.65 (±0.34)*	7.2 (±3.9)	5.1 (±3.1) *	0.40 (±0.45)	0.91 (±0.05)*	4.8 (±2.8)	2.1 (±1.1) *	lat. and med. knee, forefoot, heel
shoulder	flexion/extension	0.96 (±0.02)		7.1 (±3.8)		good markerless tracking (high standard deviations of angle difference because of diff. defined shoulder joint centers)				
	abduction/adduction	0.89 (±0.16)		2.8 (±1.2)		0.94 (±0.05)		2.5 (±1.5)		lat. elbow, triceps
	rotation	0.49 (±0.50)		39.1 (±51.9)		0,95 (±0.03)		4.9 (±4.1)		lat. elbow, triceps
elbow	flexion/extension	0.42 (±0.70)		20.6 (±28.3)		0.92 (±0.07)		4.1 (±2.6)		lat. elbow, triceps

* Markerless and hybrid tracking results compared to full-marker-based tracking in Simi Shape without using silhouette correspondences (the same model was used)

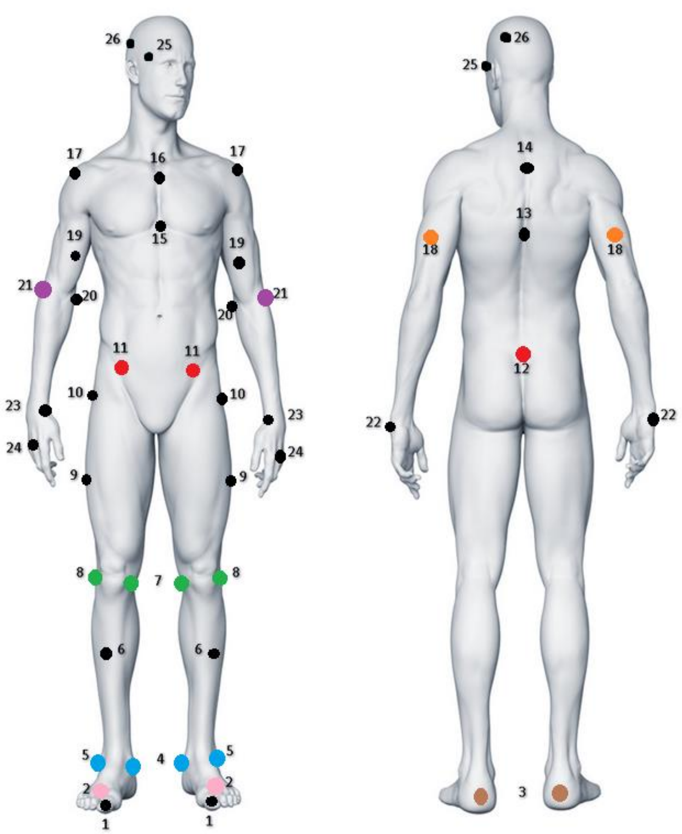

Figure 1: Full body marker based setup – Hybrid tracking markers highlighted

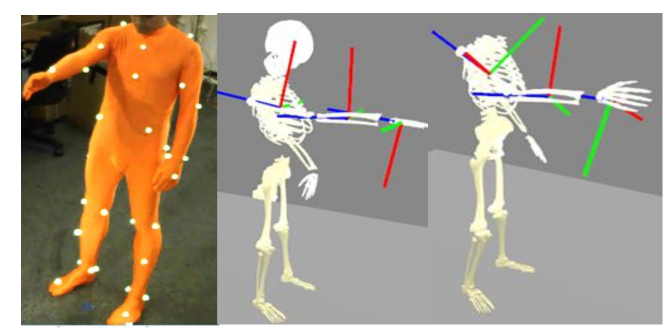

Figure 2: Camera image, marker based data, markerless data

Discussion: This study shows that markerless tracking can achieve good results for some joint angles performing different and complex movements. 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 to achieve good joint angle results for complex movements. By using a total of 19 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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