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An Equivalent Shoulder Model for Real-time Motion Capture and Reconstruction

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Abstract
Having the possibility of performing a motion capture and reconstruction in real time may be useful for online checking of the capture validity and for biofeedback-based real-time applications, in which the subject's motion is required as input, as those in the field of rehabilitation, sport, gaming, cinema, etc.
In a previous work [1], the authors have proposed an Extended Kalman Filter (EKF) based method for the motion capture and for its real-time reconstruction that, additionally, overcomes some of the problems that are inherent to the optical motion capture, as it is the problem of marker trajectory reconstruction, especially critical when some markers are lost due to occlusions.
So far, the method had been used with subject models in which the shoulder was defined by means of a spherical joint directly connecting humerus to thorax. However, for certain movements, this modeling is not acceptable, the shoulder having to be modeled by the closed chain formed by thorax, clavicle and scapula [2]. The problem when doing so is the inclusion of closed chains in the model, which hinders the use of the EKF based method, as it requires that the coordinates defining the model are independent.

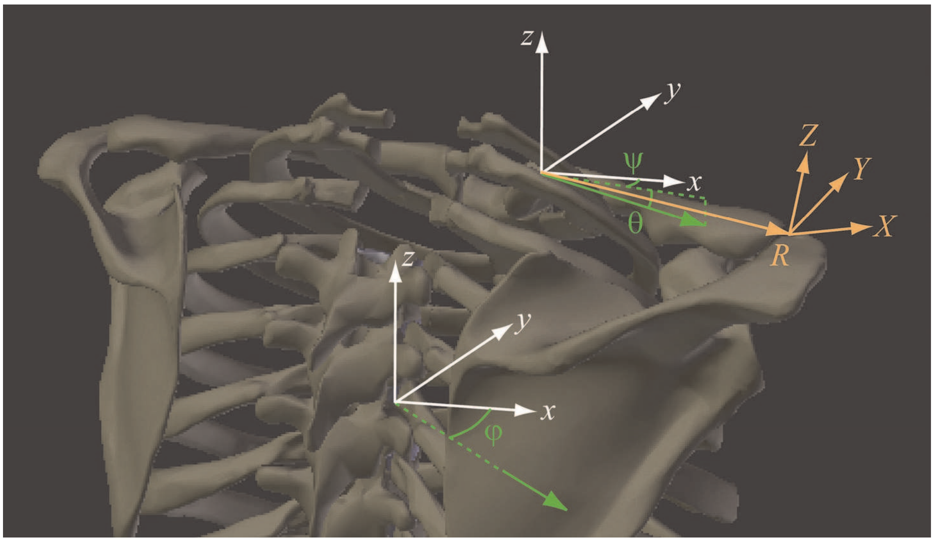

Figure 1: Inputs and outputs of the macro-joint defined at the shoulder.

To address the mentioned problem, in this work it is proposed to model the shoulder by means of the macro-joint shown in Figure 1, where (x,y,z) is the local reference frame of the thorax. The macro-joint inputs are the two angles that define the relative motion of the clavicle with respect to the thorax, ψ and θ, and the angle φ which defines the relative motion of the scapula with respect to the thorax once the position of the acromio-clavicular joint, R, has been set. The macro-joint outputs are the angles that provide the orientation of the local reference frame of the scapula, (X,Y,Z), with respect to the thorax.

To check the utility of the proposed modeling, an experiment was carried out that consisted of capturing the movement of a subject throwing a ball with his hand, as can be seen in Figure 2. The cameras recorded the positions of the markers along the time, and those positions were processed by means of the EKF based method in the three following ways: (i) by using an open-loop model, in which the two constraints imposing the motion of the scapula on the thorax surface were not considered; (ii) by using an open-loop model, in which the shoulder was modeled with the macro-joint described before; (iii) by using a closed-loop model, in which the nonlinear position problem was solved at each time step by a Newton-Raphson iteration, so that the constraints due to the closed chains were satisfied.

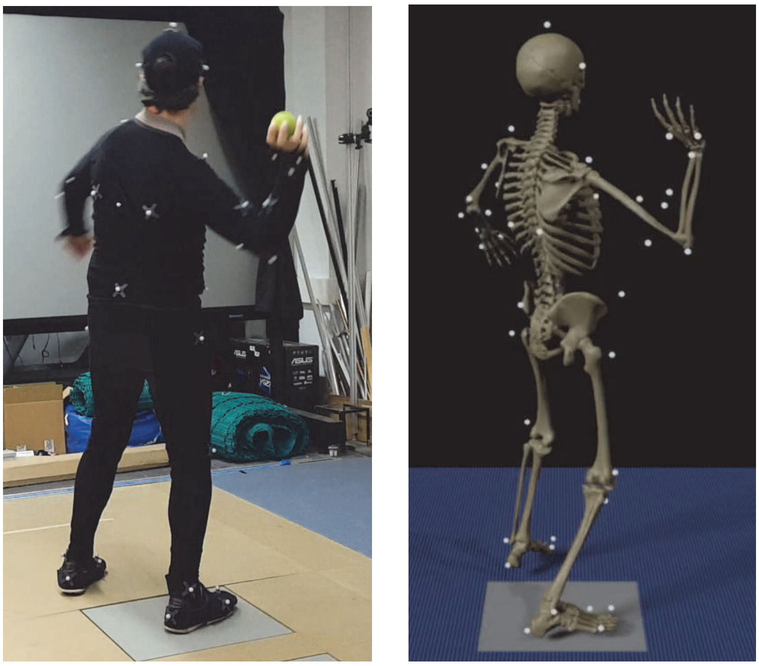

Figure 2: Motion capture and reconstruction of a subject throwing a ball.

The history of the local position vector of the center of the glenohumeral cavity with respect to the thorax was used for comparison among the three methods, taking as reference the result obtained with the third method, and calculating the error of the two other methods as the RMS error along the full motion. The CPU-times required in each case were measured too, so as to evaluate the computational cost of each method and to check that the EKF based method can be employed for motion capture and reconstruction in real time. Results of comparison are gathered in Table 1.

Table 1: Accuracy and efficiency of the three methods compared.

Method	**RMS error (mm)**	**Real-time/CPU-time**
Open loop	21.30	4.63
Macro-joint	0.02	4.35
Closed loop	-	3.60

As it can be seen, the macro-joint based method proposed in this work offers a similar efficiency to that provided by the open-loop method, but with a much better accuracy. Moreover, its accuracy can be further improved as the resolution of the generated look-up tables becomes finer (2° in Table 1), at the cost of increased RAM usage (along with longer table-generation time at the preprocessing stage).

References

[1] Lugris, U.; Vilela, R.; Sanjurjo, E.; Mouzo, F.; Michaud, F.: Implementation of an Extended Kalman Filter for Optical Motion Capture with Real–time 3D Visualization. In Proceedings of the 5th Joint International Conference on Multibody System Dynamics (IMSD), Lisbon, Portugal, June 24-28, 2018.

[2] Quental, C.; Folgado, J.; Ambrosio, J.; Monteiro, J.: A Multibody Biomechanical Model of the Upper Limb Including the Shoulder Girdle. Multibody System Dynamics, Vol. 28, No. 1-2, pp. 83-108, 2012.