Optimization-Based Differential Kinematic Modeling Exhibits a Velocity-Control Strategy for Dynamic Posture Determination in Seated Reaching Movements

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We proposed a velocity control strategy for dynamic posture determination that underlay an optimization-based differential inverse kinematic (ODIK) approach for modeling three-dimensional (3-D) seated reaching movements. In this modeling approach a four-segment seven-DOF linkage is employed to represent the torso and right arm. Kinematic redundancy is resolved efficiently in the velocity domain via a weighted pseudo-inverse. Weights assigned to individual DOF describe their relative movement contribution in response to an instantaneous postural change. Different schemes of posing constraints on the weighting parameters, by which various motion apportionment strategies are modeled, can be hypothesized and evaluated against empirical measurements. A numerical optimization procedure based on simulated annealing estimate the weighting parameter values such that the predicted movement best fits the measurement. We applied this approach to modeling 72 seated reaching movements of three distinctive types performed by six subjects. Results indicated that most of the movements were accurately modeled (time-averaged RMSE less than 5) with a simple time-invariant four-weight scheme which represents a time-constant, inter-joint motion apportionment strategy. Modeling error could be further reduced by using less constrained schemes, but notably only for the ones that were relatively poorly modeled with a time-invariant four-weight scheme. The fact that the current modeling approach was able to closely reproduce measured movements and do so in a computationally advantageous way lends support to the proposed velocity control strategy.