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A Forward-Muscular Inverse-Skeletal Dynamics Framework for Human Musculoskeletal Simulations

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Abstract

This study provides a forward-muscular inverse-skeletal dynamics framework for musculoskeletal simulations. The simulation framework works based on solving the muscle redundancy problem forward in time parallel to a torque tracking between the musculotendon net torques and those from inverse dynamics. The proposed framework can be used by any musculoskeletal modeling software package; however, just to exemplify, here in this study it is wrapped around OpenSim and the optimization is done in MATLAB. The novel simulation framework was highly robust for repeated runs and produced relatively high correlations between predicted muscle excitations and experimental EMGs for level gait trials. This simulation framework represents an efficient and robust approach to predict muscle excitation, musculotendon unit force, and to estimate net joint torque.

Introduction:

Different approaches have been used in musculoskeletal simulation studies to solve the muscle redundancy problem. Fully forward dynamics (Anderson and Pandy, 2001; Shourijeh and McPhee, 2014b; Shourijeh et al., 2016), fully inverse dynamics (Ackermann and Schiehlen, 2009), inverse-forward dynamics (Shourijeh and McPhee, 2014a), and forward-inverse dynamics (Lloyd and Besier, 2003; Olney and Winter, 1985b) have been applied with different optimal control strategies in static, partially dynamic, or fully dynamic prediction horizons. Out of those, forward-inverse dynamics simulations have been mostly used for EMG-driven simulations. A variety of EMG-driven models have been developed for the lower extremity (Buchanan et al., 2004; Buchanan et al., 2005; Gerus et al., 2010; Lloyd and Besier,

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