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Control-Oriented Muscle Torque (COMT) Model for EMG-Based Control of Assistive Robots

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Extended Abstract

Owing to musculoskeletal disorders, occupational hazards, congenital diseases, and aging, there is much research into assistive devices. For power augmentation, rehabilitation, and as artificial replacements to body segments, bio-signals are one of the primary inputs of the volitional controller embedded within the biomechatronic devices. Among biological signals, electromyography (EMG), which is the measurement of the electrical activity generated during the contraction of a muscle, has shown promise in interpreting human motion intention for controlling robotic prostheses and exoskeletons (Exo)s [1].

Fundamentally, there are two methods for mapping EMG channels to the torque of assistive robotic devices: the Hill-type muscle model [2] and machine learning methods. First, the EMG signal can be considered as input to the Hill-type model. Having these muscles models within the model bears several shortcomings, including complex musculoskeletal geometry, actuator redundancy, and difficult-to-fit parameters for each muscle. Second, using machine learning requires a considerable amount of data (spanning different conditions) for training the model. We propose a potential solution to the difficulties associated with both of these methods: the Control-Oriented Muscle Torque (COMT) model. The COMT model mimics elements of muscle modelling (i.e. the kinematic dependence of muscle actuation) in joint torque calculations; however, individual muscles are not explicitly modelled. This simplifies the EMG-torque relationship to be mapped using machine learning. As a result, we hypothesize that less data is required to map the EMG channels to the assistive torque.

The COMT model is the summation of (1) passive torque with the product of (2) torque-velocity scaling, (3) torque-angle scaling, and (4) activation torque. Functions (2,3) mimic the position/velocity dependence of muscle in the musculoskeletal system. Additionally, a nonlinear passive torque function (1) is introduced to mimic the effects of viscoelastic structures surrounding the human joint. Functions (1-3) should be defined relative to the actuator frame instead of the standard anatomical frame; converting standard anatomical Muscle Torque Generators (MTG) [3] to the actuation frame in control loops is time-consuming and requires extra measurements of standard anatomical motion. To this end, there are two methods of identifying functions (1-3): (i) using dynamometry (Biodex System 4 Pro; Biodex Inc, USA) or (ii) transforming the results from the MTG. For (i), rotations of the joints-of-interest should be isolated in the plane perpendicular to the rotation vector of the robotic joint. A linear least-squares solver then may be used to fit the relevant functions to the experimental data. For (ii), we used the MTG functions of McNally et al. [4], then transformed these functions (1-3) to resolve flexion/extension and adduction/abduction torques to the shoulder Exo (Levitate Airframe) elevation frame. This transformation made use of the Jacobian matrix of the velocities for these two standards. Finally, we will use machine learning to calculate function (4) from measured EMG. This COMT model will be used for EMG-based control of an Exo.

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