BIOMIMETIC MODEL-BASED HAND CONTROL: PROGRESS AND CHALLENGES FOR MYOELECTRIC PROSTHETICS

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ABSTRACT

Commercial upper-limb prostheses are functionally constrained by the lack of suitable myoelectric control signals. Although dexterous prosthetic hands are becoming more available on the market, controlling these devices often requires non-intuitive methods, such as inertial measurement units placed on the feet, or more commonly, selection of a grasp pattern followed by actuation. These control methods have a key factor in common; they require non-intuitive signals to replicate what able-bodied people achieve effortlessly. More advanced approaches, typically based on pattern recognition algorithms, are being developed to provide more intuitive control. However, as we move towards simultaneous control of the wrist and individual fingers, even these approaches face challenges. Here, we propose an alternative method that leverages anatomical and physiological knowledge of muscle function and hand biomechanics to create a biomimetic musculoskeletal control system. This approach assumes that multi-channel, fully implanted myoelectric recording systems, currently under final evaluation and testing, will be available in the near future. Here, we describe the general framework for this biomimetic controller and highlight some of the progress, as well as challenges, in developing such a system.

All procedures were approved by the University of Pittsburgh Institutional Review Board and the US Army Human Research Protection Office. Nine able-bodied subjects and one transradial amputee were enrolled in the study. Intramuscular EMG data were recorded from 16 fine-wire electrodes placed in the extrinsic hand and wrist muscles under ultrasound guidance. EMG and kinematic data were collected during structured hand and wrist movements.

At present, we have implemented a system that enables real-time control of simulated or physical prosthetic hands. We use Hill-type muscle models (29 muscles) and forward dynamic stimulations in MuJoCo to convert muscle activations, estimated from EMG signals, to muscle force, then joint torque, and ultimately movement. For the 18 mechanical degrees-of-freedom (DOF) and 29 muscles, this can be achieved in less than 1 ms. These simulations are generally stable, although noise in EMG signals and limited modelling of muscle activation-contraction dynamics, may limit current performance. Simultaneous control of 3-4 DOF is routinely achieve, although maintaining static postures remains a challenge. We are currently comparing simulated kinematic outputs to ground truth kinematics from able-bodied subjects to identify and evaluate the impact of changing model parameters. We believe that this overall approach will eventually enable restoration of dexterous prosthetic hand movements by encapsulating the normal musculoskeletal dynamics within the model while limiting reliance on training data sets.