HIGH DEGREE-OF-FREEDOM CONTROL OF VIRTUAL AND ROBOTIC PROSTHETIC HANDS USING SURFACE EMG

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ABSTRACT

Dexterous, intuitive, multi degree-of-freedom (DOF) control of a prosthetic hand is a highly sought after feature for next-generation multi-articulated robotic prosthetic hands. Here we present results of ongoing studies in which transradial amputees and intact subjects instrumented with 14-to-22-electrode surface EMG (sEMG) assemblies were able to simultaneously control 6-to-8-DOF of a virtual or robotic hand, and generate novel grasps that were not previously trained.

Subjects were instrumented with up to 22 “wet” sEMG electrodes (Coviden, Mansfield, MA), or a sleeve containing ≥ 14 dry “button” electrodes (Motion Control, Salt Lake City, Utah) placed on the forearm or residual forearm clustered above digit and wrist muscles. Decode calibration data was collected at 1kHz using a bioamplifier (Ripple LLC, Salt Lake City, Utah) while the subjects followed repeated single-DOF movements of a virtual hand (e.g., index finger flexion) and one full-hand grasp movement. Data were filtered with a 15-375Hz bandpass filter. Amplitude of single-ended and software-differenced channel pairs were computed, binned in 33 ms windows, and used as the input to a Kalman filter decode algorithm, capable of position or velocity decoding modes. To further minimize crosstalk between DOFs, experimenter-selected gains and thresholds were applied to the outputs, which were then used to control in real-time a virtual hand in a virtual environment (MuJoCo), or a 6-DOF robotic prosthetic hand (DEKA, Manchester, NH). Individual DOF control was verified by means of a virtual target-touching task, where subjects were instructed to touch and hold single or multiple-DOF targets while holding the non-target DOFs in a neutral position. Multi-DOF, untrained movements and grasp and positions were further evaluated using the robotic or virtual hand during functional tests such as utensil holding and cup pouring.

A transradial amputee, using a 22-wet-electrode sEMG assembly, achieved 8-DOF control in a target-touching task (45/48 successful trials), similar to his performance using an implanted 32-electrode EMG assembly (47/48 successes). An intact subject was capable of 6-DOF control in a target-touching task using a 14-dry-electrode sEMG sleeve (30/30 successes). Subjects were also able to demonstrate the ability to make novel grasps (such as thumb-index pinch) in the virtual environment.

These studies show that simultaneous high-DOF control of a prosthetic hand using sEMG is possible and similar in performance to iEMG assemblies within sessions, although long-term stability has not yet been demonstrated. Our decoding strategies represent a novel and effective alternative to the commonly used “direct control” or nominal classifier strategies.