SIMULTANEOUS CONTROL OF A VIRTUAL MULTI-DEGREE OF FREEDOM PROSTHETIC HAND VIA IMPLANTED EMG ELECTRODES

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ABSTRACT

The loss of a hand can have a profound, life-altering impact on an individual's life. Recent advances in dexterous myoelectric hands now afford a device that can come close to replicating the range of grasp shapes possible by the natural hand. However a bottle-neck remains regarding the ability to naturally convey enough information to control the multi-degree of freedom (DOF) hands now available. This work describes the deployment of an intuitive multi-DOF command interface that uses permanently implanted EMG electrodes in the muscles of the residual limb and machine learning techniques to decode user motor intent.

This paper covers the results of the first recipient of such a system. The implanted portion consists of eight bi-polar EMG electrodes surgically placed within the proximal muscles of the wrist and fingers. The leads were tunneled under the skin to the upper arm and exit percutaneously. A cued posture matching task was used to train the system to recognize user intent to control the simultaneous velocity of three degrees of freedom – hand aperture, wrist flex/extension, and wrist rotation. An artificial neural network (ANN) was used to convert key magnitude and frequency-related features of the EMG signals into continuous joint velocity. An ensemble approach was used whereby the coincident features of all eight EMG signals are used as inputs instead of the one-muscle, one-action agonist/antagonist command approach used in more conventional myoelectric prosthetic hands. A virtual reality (VR) posture matching task was used to test system performance. The performance of the intact hand was used as a standard for comparison.

The results of this work have shown that the implanted electrodes offer superior signal to noise ratio and less electrical interaction between electrode pairs than that seen using surface EMG recordings. User signals for specific hand motions have been consistent over several months, allowing for literal plug-and-play operation without the need for regular re-calibration. Compared to the intact hand, the ANN decoded movements exhibited no significant difference ($p > 0.05$) in terms of Trial Time (3.39±0.13 vs.2.82±0.21 s), Overshoot (41±8% vs.48±8), or Success Rate (100%), though they did exhibit a slightly reduced Path Efficiency (57±2 vs. 66±2%) and slower Movement Speed (18±0.5 vs. 22±0.4 %ROM/s).

This work demonstrates the potential benefits of coupling machine learning techniques with implanted ensemble EMG recording. Improvements in signal quality yielding more consistent signals can possibly afford prosthetic hand performance on par with the intact hand.