Developing a Brain-Computer Interface for Control of an Upper-Limb Neuroprosthesis

by

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Abstract

A Brain-Computer Interface (BCI) uses electrophysiological measures of brain activity to communicate with external devices, bypassing normal neuromuscular pathways. Neural activity can be recorded from either within the cortex (single-units), the surface of the brain (electrocorticography [ECoG]), or the scalp (electroencephalography [EEG]). Recent breakthroughs in BCIs have enabled practical applications and opened up the possibility for direct neural control of a prosthetic limb and restoration of motor control for amputees, the paralyzed, and those with degenerative muscular diseases.

A large portion of this thesis focuses on the design of two different BCI systems for control of an upper-limb neuroprosthesis. First, a novel noninvasive EEG-based BCI is described for 1-D control of a prosthetic hand. This BCI system uses haptic feedback and a context-sensitive control strategy to allow subjects to grasp objects of various sizes without slipping. Second, an invasive intracortical BCI is described for dexterous control of an advanced multi-fingered prosthetic hand. Using neuronal recordings from the primary motor cortex of primates, real-time decoding of flexion and extension of individual fingers and the wrist is demonstrated for the first time, and with high accuracy.

The remainder of this thesis describes how cortical control strategies can be implemented in a Virtual Integration Environment (VIE), and be used to systematically evaluate and validate different algorithms prior to building the final mechanical prosthetic limb. Lastly, the framework for future studies is discussed, with a focus on improving the cortical control algorithms for closed-loop control. The final vision is to integrate the algorithms into the final biomechanical limb under human control.