Revolutionizing Prosthetics 2009: Dexterous Control of an Upper-Limb Neuroprosthesis

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The Revolutionizing Prosthetics 2009 project, which seeks to develop a revolutionary 23-degree-of-freedom upper-limb prosthesis, spans multiple institutions and disciplines. APL serves as the system integrator, coordinating efforts among the various institutions and participants. One of the revolutionizing goals of the program is to produce a fully neurally integrated upper-extremity prosthetic. Data provided from neural signals in the motor cortex, nerve fibers of the peripheral nervous system, and surface or intramuscular myoelectric signals will be acquired and processed to provide command signals to the prosthetic device. This paper highlights one aspect involving collaboration between JHU's Biomedical Engineering Department and APL to provide dexterous finger control.

The collaboration focused mainly on algorithm development, where researchers in APL's National Security Technology Department and JHU's Biomedical Engineering Department concentrated on developing signal-analysis (SA) algorithms for decoding motor cortex signals associated with finger movement. Researchers in APL's Air and Missile Defense and National Security Technology Departments focused on developing feedback control algorithms for driving the electromechanical hardware making up the prosthetic hand (Fig. 1).

SA algorithms have been developed to take single-unit activities and local field potentials from the primary motor and premotor cortex to decode an entire suite of dexterous movements, such as individual flexion/extension of each finger and grasps. Independent decoding filters were designed for each set of dexterous movements by using feedforward artificial neural networks. A novel hierarchical classifier was used to asynchro-
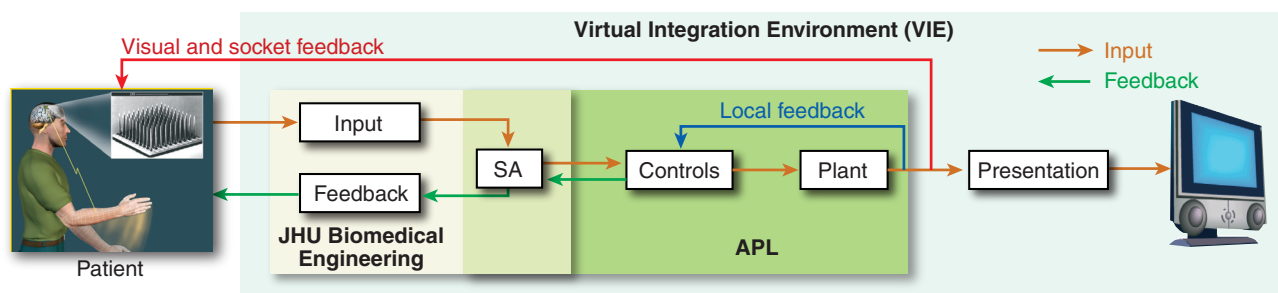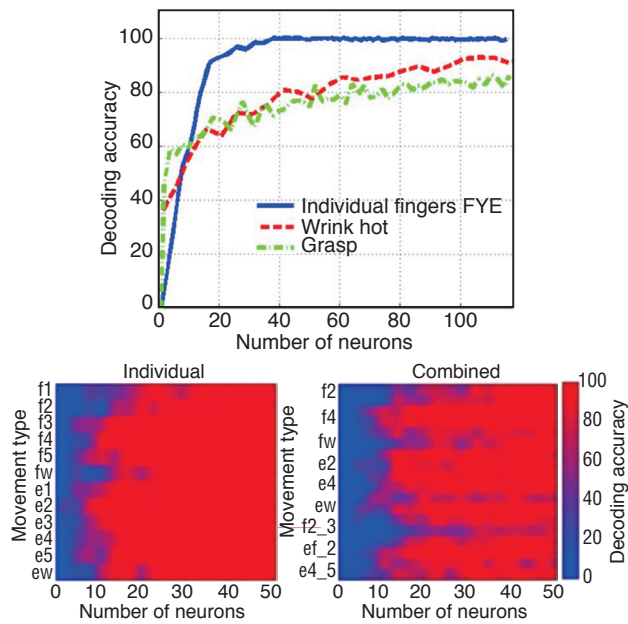

Figure 1. Feedback control in the VIE.

Figure 2. Motor cortex spike decode data.

Figure 3. A mechanical hand (left) and its impedance-controlled equivalent (right).

nously decode movement using neuronal spikes and then send command signals to control algorithms running on embedded processors in the prosthetic device (Fig. 2).

The control algorithms were designed for specific electromechanical hardware with stringent weight and torque requirements, resulting in a hand with highly geared finger motors. Consequently, when the hand interacts with external objects, large contact forces can develop. An "impedance-control" approach was developed to handle this challenge. Here, joint torque and motion feedback are used to create a closed-loop control system that forces the hand to exhibit a programmable joint stiffness, damping, and inertia that are much different than what the mechanical hardware provides. This configuration can give the hand a much more human-like characteristic.

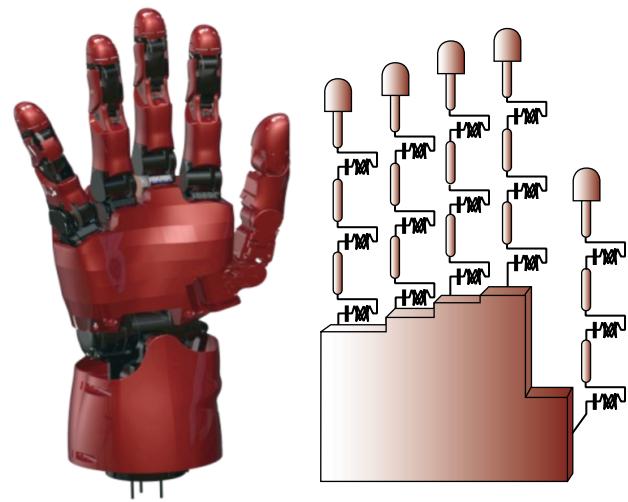The SA and control algorithms from each collaborator are tested together in a virtual integration environment (VIE). The VIE is a software framework for coordinating distributed engineering design efforts. The VIE can therefore be used to visualize and monitor the performance of various design approaches, neural SA algorithms, and control algorithms; simulate emerging mechatronic elements; train end users to control real or virtual neuroprosthetic devices; and configure and customize take-home devices.

For further information on the work reported here, see the references below or contact michael.bridges@jhuapl.edu.

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