Simulation of an Above-Elbow Myoelectric Prosthetic Arm
For Development of an Implanted Myoelectric Control System

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Introduction

The simulator necessary for preliminary experiments involves three parts: real-time measurements of subject data, simulation of the prosthetic, and a visualization of the arm. Basic versions of all components were developed, allowing for development of the simulator’s integration framework. This work focuses on the prosthetic simulation and integration; other components have been developed by collaborators for integration.

The simulator provides the subjects with feedback. Unfortunately, current myoelectric prostheses have several disadvantages:

- Limited number of DOFs
- Sequential, uninitiative control
- Long donning/doffing time

Many of these limitations stem from the use of surface electrodes, which reduce the number of available muscles, and yield inconsistent control signals.

The restricted capabilities of UE prostheses has led to low acceptance rates among amputees. The use of implanted EMG electrodes has the potential to overcome these existing limitations. An implantable system would increase the number of available muscles and yield consistent control signals. These improvements, in turn, make increased DOFs and more natural control feasible. An implanted system also greatly reduces the donning/doffing time of the device.

Project Scope

The ultimate aim of this project is to create an implantable EMG control system for use in UE prostheses. To reduce human experimentation, preliminary investigations will be conducted using musculoskeletal models.

To provide natural motion of the residual limb, a prosthetic system, a simulation incorporating their interactions is key. This requires simulation of the mechanical properties of the prosthetic and recordings of residual limb position.

By integrating this simulation with real-time measurements of EMG signals from selected muscles, the system’s response to a subject’s movements can be evaluated. Incorporating a visual representation of the arm’s response also provides the subject with feedback.

This project develops a basic prosthetic model and the framework required for this multi-component system.

Real-Time Measurements

- Polhemus FASTRAK electromagnetic motion analysis system used
- Sensors placed on trunk and residual limb
- 3D position coordinates and angles (roll, pitch, yaw) measured and imported into SimMechanics
- Polhemus system set-up and integration developed by Noah Marciniak
- Surface electrodes used to obtain muscle signals
- Gated, amplitude-based control used to determine joint actuation
- Joint actuation modulated via velocity, with feed-back control loop
- EMG acquisition/processing and integration developed by Chris Pulliam

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Fig. 1. Schematic of a myoelectric prosthesis.

Fig. 2. Schematic of preliminary optimization experiment set-up. EMG signals are recorded from select muscles and used to drive the simulator.

Fig. 3. Flow Chart outlining the flow of information within the simulator. Real-time measurements encompass monitoring residual limb position and EMG signals from selected control muscles. Each of these components provides different information for the mechanical prosthetic model. Finally, kinematic data for the residual limb—prosthetic system are sent to visualization software (GameStudio).

Fig. 4. Polhemus FASTRAK system [3].

Fig. 5. Virtual representation of the SimMechanics prosthetic model

Future Work

Preliminary results demonstrate the feasibility of this multi-component simulator. However, the Plumes system introduces a small latency, reducing accuracy of real-time simulation. This electromagnetic-based system also experiences interference from external radiation. Furthermore, the current prosthetic model is a very basic of the Utah Arm 3, and does not provide a realistic kinematic response. In-depth modeling of the prostheses’ properties (i.e. motor response times, moments of inertia, etc.), incorporating design specifications, is required before the simulator will be fully operational.

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References


Further Information

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Arm Visualization

Fig. 6. GameStudio Arm visualization with target.

Results and Discussion

Preliminary results demonstrate the feasibility of this multi-component simulator. However, the Plumes system introduces a small latency, reducing accuracy of real-time simulation. This electromagnetic-based system also experiences interference from external radiation. Furthermore, the current prosthetic model is a very basic of the Utah Arm 3, and does not provide a realistic kinematic response. In-depth modeling of the prostheses’ properties (i.e. motor response times, moments of inertia, etc.), incorporating design specifications, is required before the simulator will be fully operational.

Future Work

This project develops the framework and integration schemes for creating a multi-part simulation of a myoelectric prosthetic system. Steps must be taken to improve the modeling of the prostheses. Updating the simulator to incorporate a more accurate motion analysis system, such as the optical-based OptoTrak system, may also improve simulator performance. With a more accurate model constructed, validation of its behavior must be performed.

The myoelectric above-elbow prosthetic simulation here is only a first step towards our goal of improving UE prostheses. Once fully developed and validated, the simulation will be used to (i) evaluate control algorithms and their ability to control multiple degrees of freedom (ii) assess which muscle combinations yield the most natural control.