MUSCULOSKELETAL MODELING OF AN EMG-BASED NEUROPROSTHESIS FOR ARM FUNCTION

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INTRODUCTION

Individuals with C5/C6 Spinal Cord Injury (SCI) lose control over a number of upper extremity muscles. Specifically the hand muscles are paralyzed, there is partial loss of wrist and elbow extension, and several shoulder functions are lost, including horizontal flexion and adduction. Functional Electrical Stimulation (FES) can be used to stimulate paralyzed muscles to restore function to these individuals. The goal of this project is to determine an appropriate set of muscles to stimulate and the pattern of muscle stimulation that, when combined with retained voluntary function, would provide improved arm function. The proposed approach will eventually extract movement intention from the EMG activity of muscles that are under voluntary control and uses this information to specify the stimulation levels of needed for the paralyzed muscles.

METHODS

Experiments were performed to measure the kinematics of a set of arm movements that reflect a wide range of daily activities. These kinematics were used as the input to a musculoskeletal model [1] in the performance of inverse dynamic simulations. These simulations generated a set of muscle activations that would produce each of the movements while minimizing the sum of squared muscle stresses. Figure 1 shows a set of arm kinematics [2] in the upper panels and the activations of several key muscles predicted by the inverse simulations (lower panels).

We then trained a time-delayed artificial neural network (TDANN) that took several of the muscle activation patterns as inputs and another set of muscle activation patterns as outputs. Specifically, we used muscles that would be expected to have voluntary function (clavicular trapezius, scapular trapezius, clavicular deltoid, and scapular deltoid) in individuals with C5/C6 SCI as the inputs and muscles that would be expected to be paralyzed (pectoralis major, serratus anterior, medial triceps) as outputs. This TDANN was designed to predict *needed stimulation* of paralyzed muscles based on the *natural activity* of muscles with voluntary control.

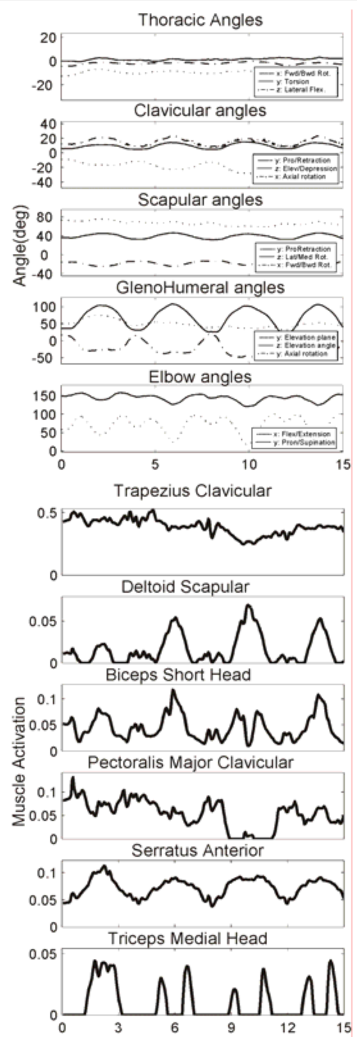

Figure 1: Musculoskeletal model inputs and outputs.

RESULTS AND DISCUSSION

Figure 2 shows an example of the ability of the TDANN to predict appropriate muscle activity. The upper panel shows the relevant arm kinematics. The next lower panel shows the "voluntary" activity of 4 muscles used as TDANN inputs. The lower 3 panels show the desired muscle activations (dotted lines) and those predicted by the TDANN (solid lines). Overall, the TDANN predictions were quite good across a wide range of different movements.

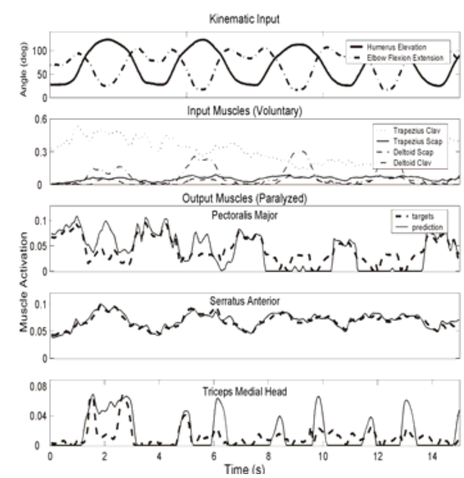

Figure 2: TDANN predictions of "paralyzed" muscle activity based on "voluntary" muscle activity.

CONCLUSIONS

The TDANN approach to predicting needed muscle activation for "paralyzed" muscles from the activation of several "voluntary " muscles has been shown to be accurate for dynamic movement conditions. This result indicates that an arm neuroprosthesis with EMG-based FES of key elbow and shoulder muscles should be feasible.

REFERENCES

1. van der Helm, F.C.T. "A finite element musculoskeletal model of the shoulder mechanism". *Journal of Biomechanics.* **Vol 27**. No 5. pp 551-569. 1994.
2. van der Helm, F.C.T. et al. "ISB recommendation on definitions of joint co-ordinate system of various joints for the reporting of human motion: Pt II. Shoulder and Elbow. *Journal of Biomechanics.* **In press.**

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