EMG Feature Selection for Simultaneous Proportional Control of Multifunctional Upper-Limb Prostheses

Anders Fougner[1], Peter J Kyberd[2] and Øyvind Stavdahl[1]

[1]Department of Engineering Cybernetics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway
[2]Institute of Biomedical Engineering, University of New Brunswick, Fredericton, New Brunswick, Canada

anders.fougner@itk.ntnu.no pkyberd@unb.ca ostavdahl@itk.ntnu.no

2010 LEIPZIG — THE 13TH WORLD CONGRESS ISPO

Summary

Simultaneous proportional control of multifunctional upper-limb prostheses has been tested on a selection of features of electromyographic signals, on data sets from 8 healthy subjects. A linear mapping function was trained and used to estimate four angles of the wrist and the hand. It appears that multiple signal features can be combined to improve the results.

Introduction

Boostani and Moradi evaluated a selection of forearm electromyography (EMG) signal features for control of upper-limb prostheses [1]. However, similar to most current research, they focused on crisp classification with ON/OFF-style state selection output.

We have reviewed these EMG signal features for simultaneous proportional control of multiple degrees of freedom. This involves a continuous mapping from a vector of EMG features to a vector of setpoints for prosthesis states to be controlled, e.g. torque, velocity or position.

The overall hypothesis is that the user will more easily adapt to a simple and smooth control function than to the discontinuous nature of crisp classification, thus achieving improved utilization of the prosthesis. Controlling multiple functions simultaneously will also permit more natural movements than controlling the functions stepwise.

Methods

Our pilot study included ten healthy subjects. Eight surface electrodes were applied to the proximal forearm, and signals were recorded during different movements involving several joints of the arm and hand. Simultaneously, pro-supination, radioulnar deviation and finger and wrist flexion/extension were recorded using VICON motion tracking equipment (marker set shown in Fig. 1).

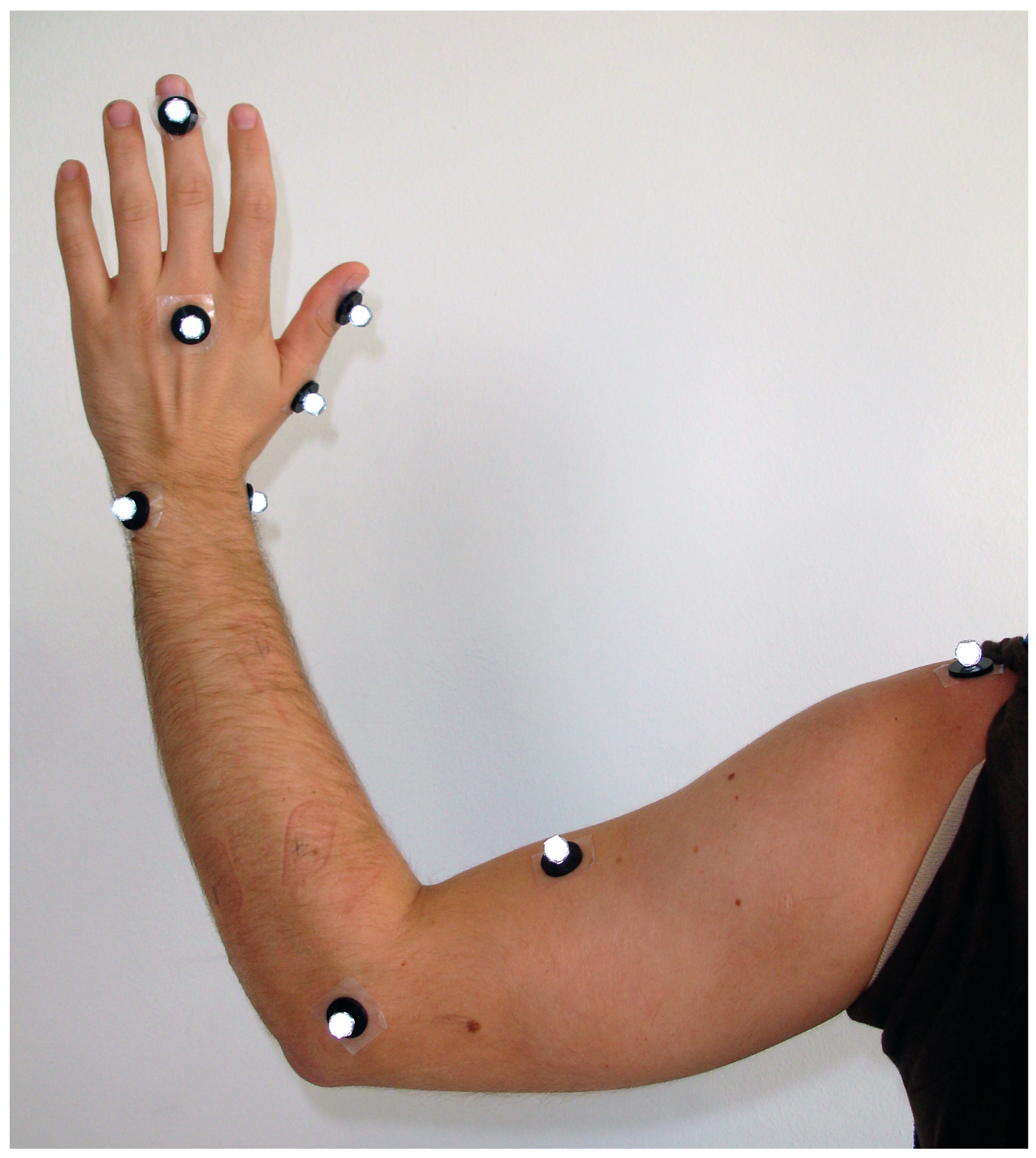


Fig. 1: VICON marker set. One marker (on ulna styloid process) is hidden.

Two recordings were made for each subject, for training and testing of the mapping function, respectively. The test set was recorded on a separate day from the training set. We used a simple linear mapping function which was trained using the pseudo-inverse for minimizing the mean square error.

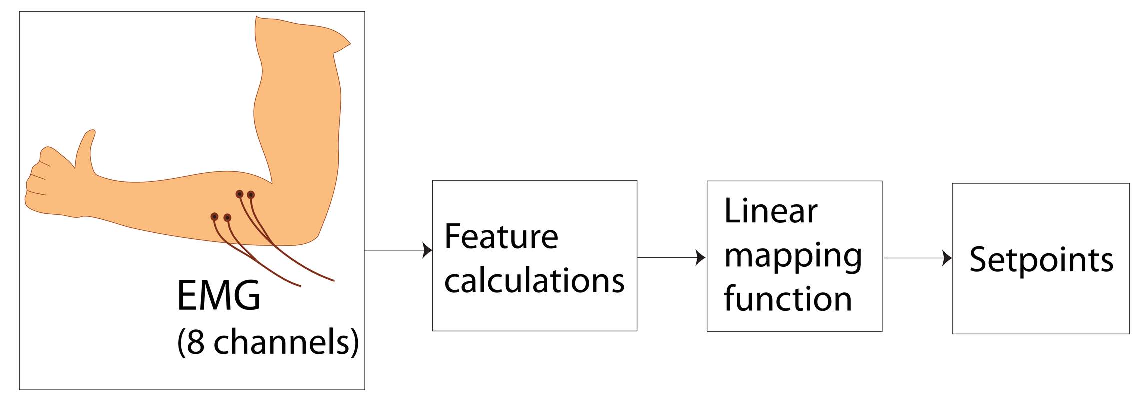
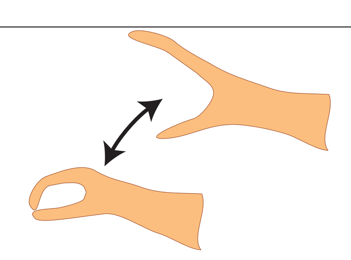
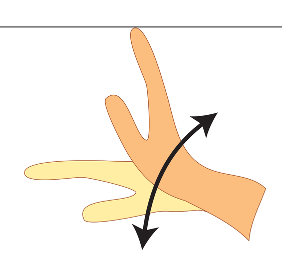


Fig. 2: Signal path.

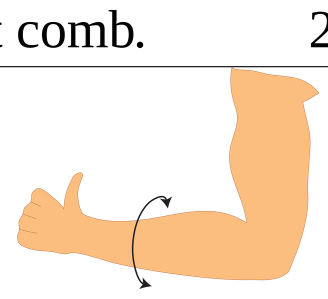
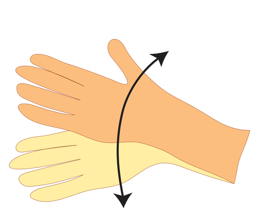
A total of 15 different EMG features were calculated [2], including time-domain and frequency-domain features as well as time-frequency representations. Up to four features were combined as inputs to the mapping function, yielding a total of 1940 possible combinations to be tested.

Results

The root-mean square error (RMSE) in % of range of motion (ROM) for the estimated angles lies in the range 20-25% for finger flexion/extension, 14-22% for wrist flexion/extension, 16-24% for pro/supination and 30-66% for radioulnar deviation (mean value for ten subjects). In all cases, a combination of four features performs better than single features. Table 1 shows a comparison between the best combination and some common single features.

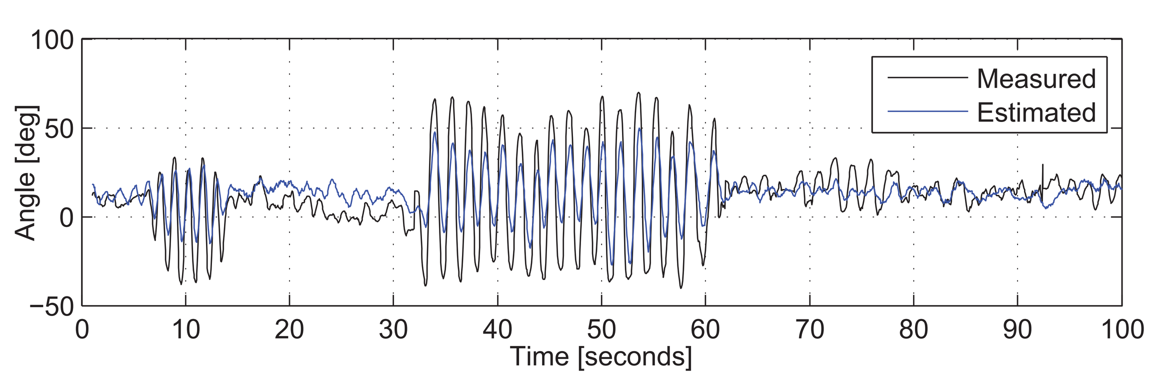
Finding flexion/extension		Wrist flexion/extension	
AAV	20.83	AAV	17.39
AAC	20.69	AAC	16.01
Best comb.	20.51	Best comb.	14.64

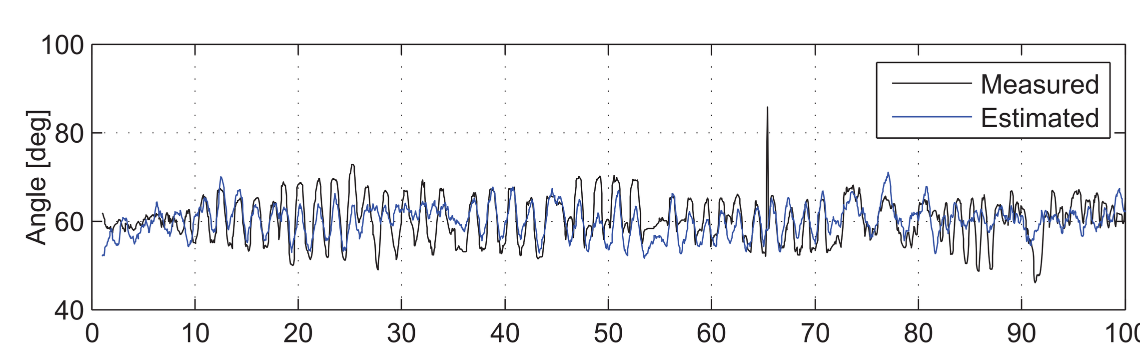
Pronation/supination		Radial/ulnar deviation	
AAV	18.52	AAV	34.67
AAC	17.70	AAC	32.84
Best comb.	16.45	Best comb.	30.60

Table 1: RMS error in % of ROM for the best among the 1940 feature combinations we tested, versus the common single features AAC (Average Amplitude Change) and AAV (Average Amplitude Value). The result is the average for all eight subjects.

For a couple of examples of estimated versus measured angles, see Fig. 3. Although Fig. 3b presents an RMS error of 37.40% of ROM, the estimate follows the fluctuations of the measured angle. We believe that the RMS error should be replaced by another measure of performance, for example correlation coefficient, both for training and testing purposes.



3a: Wrist flexion/extension. The RMS error is 14.14% of ROM.



3b: Radial/ulnar deviation angle. The RMS error is 37.40% of ROM.

Fig. 3: Example plots of measured vs estimated angle, using a linear mapping function, for the test set. The examples are for two different subjects. The input was a combination of 4 features: AR coefficients, Wilson amplitude, wavelength and zero crossings. Note that the plots show only the first 100 seconds, while the data sets last approximately 650 seconds.

Conclusions

An EMG signal that is rectified and low-pass filtered, is the most widely used feature for prosthesis control [3]. Our pilot study has reviewed a selection of 15 different signal features and shows that they can be combined to improve the results for simultaneous proportional control.

We want to continue the work on simultaneous proportional control systems, aiming for intuitive and user friendly prostheses for the end users.

References

[1] R. Boostani and M. H. Moradi, “Evaluation of the Forearm EMG Signal Features For the Control of a Prosthetic Hand,” *Physiological Measurement*, vol. 24, pp. 309–319, 2003.

[2] P. F. Bach, “Myoelectric Signal Features For Upper Limb Prostheses,” Master’s thesis, Norwegian University of Science and Technology, Trondheim, Norway, 2009.

[3] A. Muzumdar, D. F. Lovely *et al.*, *Powered Upper Limb Prostheses. Control, Implementation and Clinical Application.* Berlin, Germany: Springer-Verlag, 2004, pp. 17–33.