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

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Introduction

Boostani and Moradi (2003) evaluated a selection of forearm electromyography (EMG) signal features for control of upper-limb prostheses. 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, or a combination of these, to a vector of prosthesis states to be controlled, e.g. torque, velocity or position setpoints.

The overall hypothesis is that the user will more easily adapt to a simple and smooth control function, thus achieving improved utilization of the prosthesis.

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 motion tracking equipment. Three recordings were taken for each subject, for training, validation and testing of the mapping function. The test set was recorded on another day.

We used a simple linear mapping function which was trained using the pseudoinverse for minimizing the mean square error.

15 different EMG features were calculated, and we used all 1940 possible combinations of these when we allowed up to 4 features to be employed together as input to the mapping function.

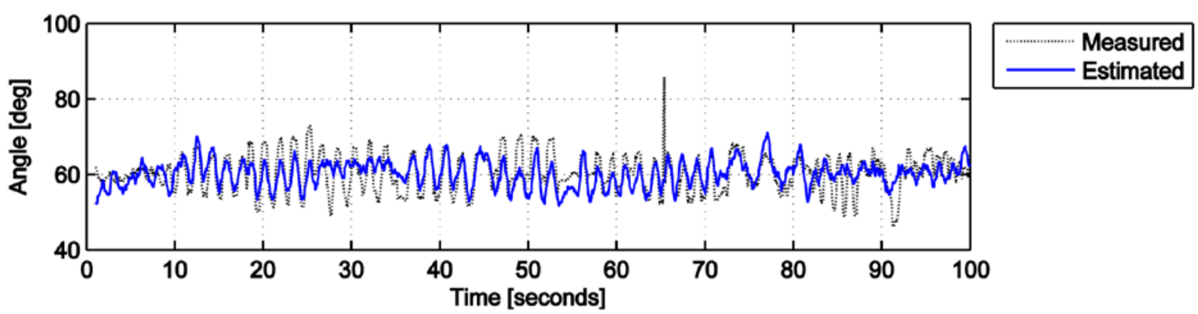

Figure 1. Example plot of measured radial/ulnar deviaton angle vs the estimate from a linear mapping function, for a test set (recorded on another day). The RMS error is 37.4% of range of motion. Input was a combination of 4 features (AR coefficients, wilson amplitude, wavelength and zero crossings).

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.

The best combination for finger flexion/extension is average amplitude change, autoregressive coefficients, cepstrum coefficients and energy loss of wavelet packet coefficients with 20.51% error (only average amplitude value/AAV: 20.83%). For wrist flexion/extension: Energy of wavelet packet coefficients, wilson amplitude, wavelength and zero crossings with 14.64% error (only AAV: 17.39%). For pro/supination: Average amplitude value, autoregressive coefficients, number of turns and wavelength with 16.45% error (only AAV: 18.52%). For radioulnar deviation: Histogram, myopulse percentage rate, number of turns and wilson amplitude with 30.6% error (only AAV: 34.67%).

For an example plot of estimated versus measured angle, see Fig. 1. Although the example plot gives 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. Of course, then it can also be used in the training algorithm.

CONCLUSION

Most widely used for prosthesis control (Muzumdar, 2004) is a rectified and low-pass filtered EMG signal as a single feature. This pilot study shows that signal features can be combined to give better results for simultaneous proportional control.

The features can be improved, and the technique for combining them can be optimized for the subject and the prosthesis state we try to estimate.

REFERENCES

Boostani R and Moradi MH (2003), "Evaluation of the Forearm EMG Signal Features for the Control of a Prosthetic Hand", *Physiological Measurement* 24, 309–319.

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