SIMULTANEOUS PROPORTIONAL CONTROL OF MULTIPLE FUNCTIONS IN UPPER-LIMB PROSTHESES

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INTRODUCTION

The possibilities of controlling multifunction upper-limb prostheses by means of EMG signals and basic Bayesian pattern recognition were demonstrated decades ago (Herberts, 1978), but due to technological limitations the results never became available for prosthesis users.

Much of today's research focuses on more complex classifiers but still predominantly with an ON/OFF-style output (so-called "digital control"), and no records indicate that these systems yield an outcome that is functionally superior to simpler approaches.

The purpose of this work is to review simple classification schemes of the past and generalise these to allow *simultaneous*, *proportional* control of multiple prosthesis joints. In mathematical terms this involves the definition of a continuous mapping *f* from a vector $\underline{v}(t)$ of EMG parameters to a vector $\underline{\theta}(t)$ of prosthesis states to be controlled, e.g. torque, velocity or position setpoints. In more common terms, we want to predict the states of the (phantom) limb based on measured EMG signals, so that the prosthesis can be made to behave accordingly. The rationale is the hypothesis that the user will more easily adapt to a simple and smooth control function, thus achieving improved utilization of the prosthesis.

METHOD

Eight surface EMG electrodes were applied to a healthy subject's 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. Two recordings were taken, one for training of the mapping functions and the other for assessment of the result (the "test set").

All EMG signals were initially bandpass filtered, rectified and low-pass filtered with a non-linear element that follows fast transients while smoothing stationary signal regions.

The mapping function $\underline{\theta}(t)=f(\underline{v}(t))$ was implemented as a linear (LF) and a quadratic function (QF) and a multilayer perceptron (MLP), respectively. The QF comprised all linear and quadratic terms including cross terms. The MLP had one hidden layer with 10-35 nodes. The mapping function parameters were then adjusted to minimize the rms difference between measured joint angles and mapping function output.

RESULTS

Fig. 1 shows the rms angle prediction errors of the control functions. Note that the QF performance is comparable to that of the best MLP. Significant cross-talk was seen between the different estimated angles.

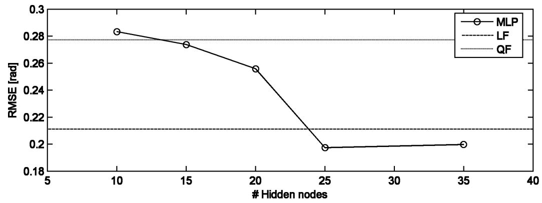

Figure 1. MLP test set performance (rms error) with different numbers of hidden nodes, compared to LF and QF performance.

DISCUSSION

The results illustrate the possibility of predicting continuous states of the limb on the basis of EMG signals. These estimated states lend themselves to be used as setpoints for a prosthesis control system. Interestingly, with the present data set the simpler FL method yield a better result than the QF. There is significant cross-talk between joint angles, which shows a potential for improvement of signal features, EMG sites and the mapping function. Future work should include exploitation of signal features that are insensitive to signal amplitude to reduce the influence of disturbances like skin moisture. Experiments with prosthesis users would depend on the user to mimic the motion of a "master hand", i.e. a computer generated graphical hand image, with his/her phantom limb in order to collect experimental data.

CONCLUSION

A simple experiment using a healthy subject has illustrated the viability of simultaneously estimating multiple limb functions in a proportional manner. Such estimates can be used for prosthesis control purposes. The method has great potential for improvement with respect to signal acquisition, processing and pattern recognition techniques used.

REFERENCES

Herberts, P., Almström, C. and Caine, K. J Bone Joint Surg, 60-B(4), 552-560, 1978

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