ADVANCED SIGNAL PROCESSING TECHNIQUES APPLIED TO CROSS-TALK REDUCTION IN FOREARM S-EMG

Gonzalo A. Garcia* and Thierry Keller
Fatronik-Tecnalia: Paseo Mikeletegi, 7; 20009 San Sebastian, Spain
*Corresponding author: ggarcia@fatronik.com

ABSTRACT

In spite of the great advances in the mechanical and electronic components of prosthetic hands, they still lack the high number of degrees of freedom present in the real human hand. That is due, not to technical deficiencies, but to the much reduced amount of independent control signals available when using surface electromyography (s-EMG) from the forearm stump or other artificial sensors. Cross-talk between adjacent muscles produces interferences that bury the s-EMG of the target muscle and reduce selectivity.

In a single case study, surface-EMG signals from an able-bodied subject’s forearm were recorded with a surface, 5x13-electrode array while the subject performed eleven different isometric contractions. In order to reduce the cross-talk between s-EMG signals from different muscles, we applied a blind source separation (BSS) technique called JADE.

Although the results are not fully conclusive, they indicate that BSS techniques could provide an important reduction in s-EMG cross-talk and hence BSS is able to increase the selectivity of recordings for myoelectric control.

INTRODUCTION

Current myoelectric prosthetic hands have generally only one or two degrees of freedom (DOF), which allow only a very limited variety of movements. Moreover, their control is just in on-off or simple proportional mode. Therefore, users cannot yet control them in a natural way. This is possibly the main reason why most users do not choose to rely on myoelectrically controlled hands in spite of their high technical level.

On the other hand, robotic hands and arms have several DOF; however, they are not suitable as prosthetic limbs mainly because they need too many signals for their control.

Trying to combine the best characteristics of robotic and prosthetic hands, several Laboratories have developed new types of artificial hands with high (even above 10) DOF. To make those devices controllable in a natural way (for example, by agonist-antagonist pairs of muscles), many more than the usual two independent myoelectric signals should be collected from the muscles located in the stump of the user. In the forearm there are 19 muscles, all of them of small size, very close to one another, and often crossing and overlapping. Therefore, when trying to record surface electromyographic (s-EMG) signals, we have to face a very high level of cross-talk among the different muscles.

In the present work, we tried to solve the problem of cross-talk between forearm muscles by employing a blind source separation (BSS); the Joint Approximative Diagonalization of Eigenmatrices (JADE) [1].

We had already applied JADE for the separation of s-EMG signals into its constituent elements (motor units action potentials).
potential trains) [2]. In addition, other researchers had satisfactory applied other BSS technique for the reduction of cross-talk in forearm s-EMG signals [3]. However, the technique they used is based also on information gathered from the frequency domain, which might render it unsuitable for long-lasting recordings, as the frequency characteristics of s-EMG change with factors such time and fatigue [4].

METHODS

Data Acquisition

A healthy, male subject participated in this experiment after giving informed consent. He sat comfortable on a chair and his right arm was fixed to a mechanical device that blocked any movement of the hand and wrist (see Fig. 1), and measured the torque exerted by each of the isometric contractions, which consisted of: flexion of the distal phalange of digits 2 to 5 (from the index to the little fingers) and then of their medial phalange; after that, wrist abduction and adduction; and finally, wrist (forearm) pronation. Each contraction was performed three times, following a symmetric, 10-second, ascend & descent ramp with peak at 50% of subject’s maximum voluntary contraction (MVC); each iteration was separated by a 3-second relax period.

A s-EMG recording was made for each of the isometric contractions with a 13x5 electrode array (model ELSCH064 from OT Bioelettronica, Torino, Italy) placed on the anterior part of the forearm as shown in Fig. 2 in monopolar mode (far reference electrode —ARBO pediatric ECG— placed on the wrist). Each of its holes features a metal ring that was filled with conductive gel; the inter-electrode distance was 8mm. The signals were acquired at 2048 samples/s.

Signal Processing

Firstly, each of the 65-channel monopolar recordings was transformed into a bipolar 60-channel signal by column subtraction (direction perpendicular to muscle fibers). JADE was then applied to the 60-channel for each of the 11 different contractions in order to obtain one representative channel for each of the contractions. The separation matrix obtained (the inverse matrix resulting from the mixing process), was then used, after normalizing, to create a weighting matrix that represented the best linear combination of channels for each of the contraction “fingerprints”. Figure 3 shows a bi-dimensional representation of the obtained weight matrices corresponding to each contraction. An “importance
matrix was then created using for each of its lines the 1x60 matrix given by JADE. This matrix was applied to each of the recordings. The most powerful channel of the output (in the sense of higher root mean square value), was then considered to be the representative contraction and therefore the one with the most powerful activity.

RESULTS AND DISCUSSION
Figure 4 shows the identified contractions. Out of the 11 contractions, six were correctly classified. Four of the remainder ones were just up to 10% less powerful than the winning contraction, and one of them was as powerful as the recognized contraction. It is worth noting that the entire processing was automatic, and no corrections were made when, for example, JADE algorithm did not yielded a representative s-EMG activity for the target contraction. For example, by adding some further signal processing such as filtering, better results could be obtained.

CONCLUSION
This approach represents a promising solution for diminishing the high level of cross-talk usually seen in s-EMG signals. It is also a faster and more economic way of classifying muscular activity form their s-EMG with respect to other sophisticated statistical or artificial neural network algorithms. With additional processing these results could be further improved.
REFERENCES


ACKNOWLEDGEMENT

The experiments were carried out at Prof. Merletti’s LISIN Lab (Torino, Italy). The authors thank him and his group, especially to Dr. Introzzi, Dr. Vieira, and to Dr. Mesin, for their invaluable help and input.