The Independent Component Approach to the Surface Multi-channel EMGs Decomposition Method

H. Nakamura¹, T. Moritani¹, M. Kotani², M. Yoshida³, K. Akazawa⁴
¹Graduate School of Human & Environmental Studies, Kyoto University, Kyoto/Japan
²Faculty of Engineering, Kobe University, Kobe/Japan
³Faculty of Engineering, Osaka Electro-Communication University, Osaka/Japan
⁴Research Institute of Engineering, Osaka University, Osaka/Japan

Introduction

It is electromyogram (EMG) that represents interference signals of electrical activities in many motor units (MUs). An EMG decomposition method is the procedure by which the signal is classified into its constituent motor unit action potential trains (MUAPTs). So far the classification to each MUAPT in multi-channel EMGs by means of an EMG decomposition method is directly performed with differences of the waveform’s characteristics in each MUAPT (Mambrito and DeLuca, 1984). The presently employed EMG decomposition methods have the following two problems: (1) only records derived from attempted isometric contractions have been decomposed because most of EMG decomposition methods employ invasive needle EMGs; (2) the processing spends extremely enormous time because it is an interactive method between an operator and the system.

On the other hand, the use of multi-channel surface EMGs has such a high applicability to measure a variety of neuromuscular activities, e.g., position of innervation zone, action potential conduction velocity and identification of a single MU. Recently, independent component analysis (ICA) has been shown to be an efficient tool for feature extraction and blind source separation (BBS) from EEG and MEG and other multi-channel bio-signal recordings (Vigario et al. 2000, Lathauwer et al., 2000). ICA maximizes the forth order statistics, called by “kurtosis”, to maximize the statistical independence between the channels. By using ICA, multi-channel signals are extracted to each subspace.

The purpose of this study is to examine the emerging technique of ICA for EMG decomposition by means of the simulated multi-channel surface EMGs. In this paper, we organized the EMG model by means of a traveling dipole (Fuglevand et al., 1992) and discuss the results performed on the simulated multi-channel surface EMGs with ICA.

Method

ICA is a novel statistical technique that aims at finding linear projections of the data that maximize their mutual independence. Assume the following basic linear statistical mode:

\[ y = Ax \]  

(eq.1)

The vector \( y \), \( n \times 1 \) matrix, is referred to as the observation vector. The source signals vector \( x \), \( m \times 1 \) matrix, is supposed to be stationary and to be statistical independent. The matrix \( A \), \( n \times m \) matrix, leads to the observed vector \( y \) by mixing with the source vector \( x \). The goal is to estimate the demixing matrix \( W \) by maximizing the statistical independence among each component in the observed
vector $\mathbf{y}$. The solution $\hat{\mathbf{x}}$ is sought in the form:

$$\hat{\mathbf{x}} = W\mathbf{y}$$  \hspace{2cm} (eq.2)

The problem requires the following assumptions: (1) the number of the observed signals is $n$ must be larger than or equal to that of the source signals $m$; (2) no time delay have effects among each channel from sources in the observed signals $\mathbf{y}$.

We assumed the 8-channel bipolar surface EMGs by a three dimensional representation of the physical situation. The action potential was modeled by a travelling dipole, and used for an analytic approach based on electromagnetic field theory. We assumed that the inter-distance of each channel was the same $d$ as the inter-distance of bipolar electrodes. The 8-channel pairs of electrodes disposed at even intervals in the latitude direction. A single MU was assumed to be a single muscle fibre. And we also supposed that the single muscle fibre lies parallel to a line drawn through each channel pair of electrodes and that the muscle fibres exist at the depth $h$ to the skin surface. The original and image dipoles were assumed to travel along the fibres. By means of the above EMG model, the potentials on all surface electrodes were calculated.

**Result & Discussion**

We performed BBS to the simulated EMGs by means of ICA. To simplify the problem and to satisfy the necessary assumption of ICA, we assumed the followings: (1) there are only three MUs in the simulated EMGs because the number of the source signals has to be smaller than or the same as that of observation signals; (2) the depth of the three MUs from the skin surface are equal; (3) and firing intervals in a single MU are nearly equal and randomly determined within the permissible range of physiology.

The Fig.2 shows an example of 8-channel simulated EMGs in 1 second by means of the EMG model under the above condition. It can be recognized in the Fig.2 that many spikes from three MUs are included in the simulated EMGs and that each of spike intervals from a single MU is nearly equal. Also note that the spikes from a single MU is distributed on the neighboring channels and have no time delay among distributed channels. The result shows in the Fig.3 that the three trains of spikes from each single MU were separated completely to three components I.C.1-3. However, if inter-distance between muscle fibres is shorter, some MUAPTs are included in the same component.

It is indicated from the result that the application of ICA is suitable for EMG decomposition purposes and might make the processing time and artificial costs be saved in the EMG decomposition method. In our next report, real multi-channel surface EMG decomposition will be performed by means
of ICA and we’ll compare it with the result in this paper and discuss the applicability of ICA to the multi-channel surface EMGs.

References

![Figure 2](image2.png)

Fig. 2 the simulated 8-channel surface EMGs after 100-500Hz band-pass filtering.

![Figure 3](image3.png)

Fig. 3 The three MUAPTs estimate from the data in Fig. 2 by means of ICA.