UNDERSTANDING THE EEG SIGNAL DECOMPOSITION

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ABSTRACT

Decomposition of the EEG signal using independent Component Analysis (ICA) is a recently developed and practical technique for EEG data analysis. ICA method determines source signals from their mixture. This paper shows, that it is worth to determine the independent components from EEG signal. This analysis allows us to understand the sources of EEG signal. The simple example with the real EEG data is considered in order to resolve the sources of the artifacts and the sources of useful signal. It is also emphasized the clinical significance of each component and hence the importance of ICA method in clinical practice.

1 INTRODUCTION

The analysis of EEG signal is very challenging field for research and it gives place for application of several data mining and artifical inteligence methods such as classification, regresion, clustering, sequential analysis etc. One of the promising methods for EEG signal analysis is the independent component analysis (ICA) method. It solves the problem of blind source separation that is to separate the sources from their mixtures.

We assume that electroencephalographic data are composed of "some" source signals and the surface sensors gives their mixtures. Naturaly, it is useful to know the sources. We may imagine the sources as some generators of a specific waveform, e.g. epileptic spikes, spindles, K-complexes etc. There are also the sources of noise and artifacts, which should be removed.

Application of ICA method on EEG signal could be briefly divided into these sections:

- Noise and artifacts removal,
- classification of a specific waveform,
- localization of the source.

1.1 LINEAR ICA

The basic ICA problem is to find a linear transform (1) and consequently a decomposing matrix **W** so that the components **y** are as independent as possible.

$$\mathbf{y} = \mathbf{W}\mathbf{x} \tag{1}$$

It consists of finding appropriate function that measures independence. The second problem is the optimisation algorithm which finds the extrema and gives the independent components. There are a lot of methods, which solve the ICA problem. Nevertheless all of them have these basic things to approximate:

- the function that approximates the statistical independence (contrast function),
- the algorithm that optimises this function.

2 THE EEG SIGNAL DECOMPOSITION

In this section, the classical linear method for ICA is used. The method is called FastICA, [1], and solves the linear problem very precisely and reliably and rapidly.

The principle of the FastICA method is described in many ICA handbooks, such as [1], [2], etc. Unfortunately this is beyond the scope of this article, which deals with the results of the analysis and focuses on its "usefulness" for the EEG data processing.

The simple example with the real EEG data is shown below. In the figure 1 is a classical sample of EEG signal, recorded by the electroencephalograph GALILEO ESAOTE. The other figure 2 shows the independent components, evaluated by the FastICA method. The EEG specialist can easily resolve the significance of each independent component. To enlarge the comfort of the further identification, the sources localization can be evaluated and displayed, as well. The ICA results give us the information on the demixing matrix **W**. Therefore the independent components' connection with each channel of EEG signal is determined; moreover using the localization of each channel's sensor on the scalp, one can easily calculate the "scalp map" of the source signal. These maps are depicted in the figure 3.

2.1 SIGNIFICANCE OF THE SOURCES

Comparing the figures 2 and 3, one can simply see the significance of the independent components. Let's focus on the EOG artifacts, because of their obviousness. These artifacts can be seen in the pure EEG data (see the figure 1), as well. In the next picture one can find the artifact in the first signal marked as "IC 1". The scalp map of this independent component (see the figure 3, the map marked as "IC 1", too) shows its localization in the frontal area.

Furthermore, one can visualize the 3D model of the scalp for the chosen independent component. The independent component's connection with the scalp sensors (and hence the localization of the source approximation with the independent component) is demonstrated by the color of the model. This model for the 1st independent component is depicted in the figure 4. Naturally, the model could be "as-you-please" rotated.

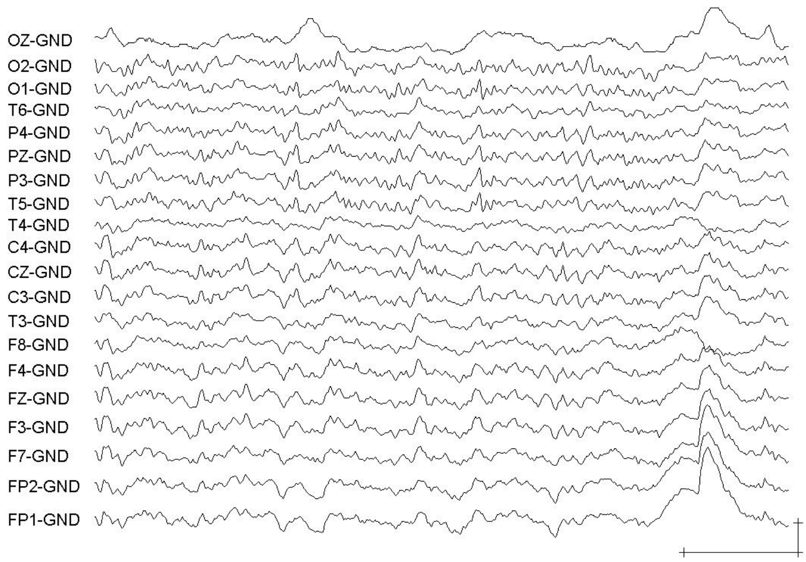

Figure 1: The sample of the real EEG signal

3 CONCLUSIONS

It has been shown, that the EEG signal decomposition is very useful technique and allows the EEG specialist to simply view the significance of the independent components. The software tool was programmed in Matlab for the reasons of research and development.

The next step of the development of this field might be the programming of this software tool in some reliable language for the application development. The future development consist in programming such an application, that can allow the specialist to use all the advantages of the ICA method. This application should allow:

- classical EEG signal techniques,
- whitening, dimension reduction,
- many kinds of independent component analysis,
- viewing of each independent component either as a time function or as a scalp map,
- modeling of the scalp with the rotation possibility and many others 3D functions.

The application development is very useful; nevertheless the further research on the ICA is necessary, too. It's obvious, that the independent components are only the EEG sources approximations. It's very difficult to estimate the amount of the useful brain signal in the independent component evaluated as an artifact. Therefore, the further research should be addressed to the theoretical ICA and its non-linear modification, as well.

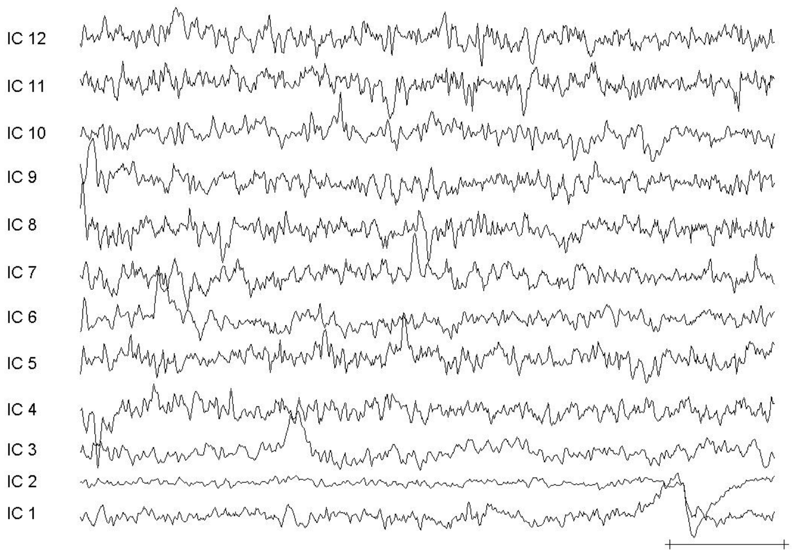

Figure 2: The most important independent components of the EEG signal

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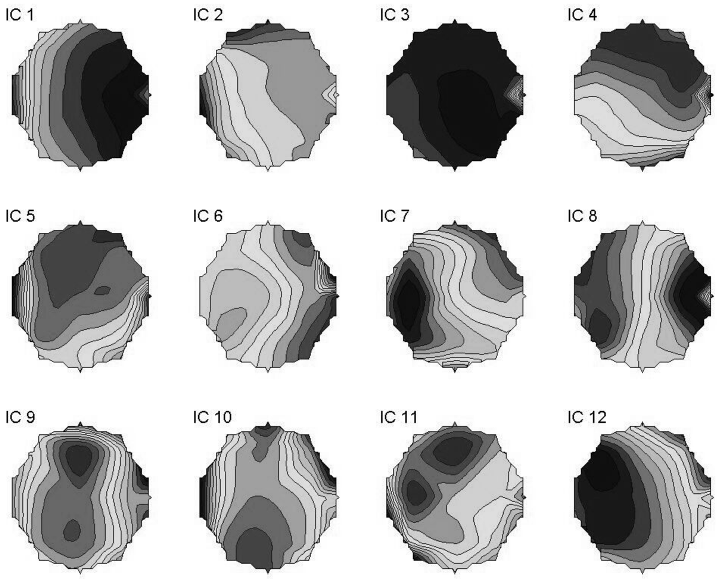

Figure 3: The scalp maps of each independent component

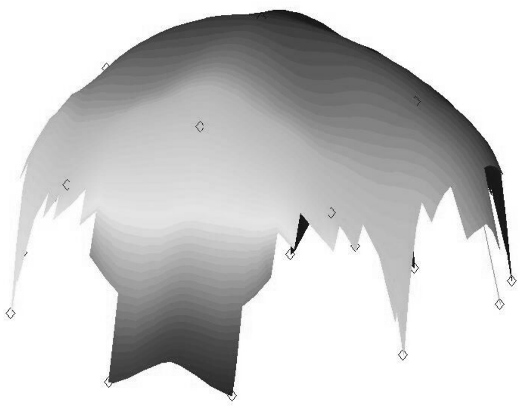

Figure 4: The 3D modeling of the scalp for the 1st independent component