Blind signal separation using prior information

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Abstract - **This article discusses the Bayesian approach to the problem of blind signal separation. Problem of incorporating prior information into a source model was discussed in this paper. The advantage of the separation algorithm, which uses a priori information, was investigated experimentally.**

Keywords - **blind signal separation, independent component analysis, Bayesian approach, abdominal ECG**.

I. INTRODUCTION

The problem of blind signals separation arises in many fields of science and technology. Solution of this problem suggests that we can determine the parameters of a linear mixing system, using the limited information about the parameters of the mixing system and about the parameters of signal sources. The most common criterion for blind separation of signals is the statistical independence of the components within the mixture. Using this criterion problem is usually referred as independent components analysis.

Method of independent components analysis is assumed that the multi-dimensional signal $\vec{x}(t_k) = \vec{x}_k$ is obtained at the output of a linear mixing system, the input of which receives several signal sources $\vec{s}_k$:

$$\vec{x}_k = \underline{A} \cdot \vec{s}_k, \qquad (1.1)$$

where $\underline{A}$ - the matrix, which characterizes the mixing system. It is assumed that we have no information about the source signals, except for their mutual statistical independence. Estimates of signal sources - statistically independent components $\vec{y}_k$ can be obtained from the mixture as follows:

$$\vec{y}_k = \underline{N} \cdot \vec{x}_k, \qquad (1.2)$$

where $\underline{N}$ - separation matrix, which is obtained by maximizing the criteria of statistical independence of desired components $\vec{y}_k$.

Possibility of separation of linear mixtures into individual components using the criteria of statistical independence was showed by Dr. Pierre Comon [1]. There are several regular methods of solving this problem. In this paper we propose a method that allows to use of a priori information to improve the separation quality.

II. BAYESIAN APPROACH WITH USING OF A PRIORI INFORMATION ABOUT THE FORM OF SIGNALS SOURCES

Using Bayesian approach we construct the score function witch is the logarithm of the posteriori probability density function and it is look like:

$$L(\underline{N}) = \ln p(\underline{A}|\vec{x}_k, I) = \ln\left[-\frac{1}{\det \underline{A}}\prod_j p_j(y_{jk})\right] + C = \\ = -\ln\det(-\underline{A}) + \sum_j \ln p_j(y_{jk}) + C, \qquad (2.1)$$

where function $p_j(s_{jk})$ - is marginal a priori probability density of j-th source signal; C - is some constant.

Using this score function we derived the next stochastic update rule for determining the separation matrix $\underline{N}$:

$$\underline{N}_{j+1} = \underline{N}_j + \mu \cdot \left(I + \vec{\varphi}(\vec{y}_k) \cdot \vec{y}_k^T\right)\underline{N}_j, \ \varphi_j(y_{jk}) = \frac{p'_j(y_{jk})}{p_j(y_{jk})}. \qquad (2.2)$$

The resulting algorithm coincides with the implementation of the algorithm Bell-Sejnowski ICA [2].

If the form of signal sources is known, this information may be used to improve the quality of the separation of these signals from the mixture. Let the form of signal sources is given by function $s_j(t_k) = s_{jk}$. Then, we can construct the a priori probability density function for k-th sample of j-th source signal as follows:

$$p_{jk}(y_{jk}) = C \cdot \exp\{y_{jk} - s_{jk}\} \cdot \left[\frac{1}{1+e^{y_{jk}-s_{jk}}}\right]^2, \qquad (2.3)$$

where s_{jk} acts as a mean value of the distribution of the source signal on the k-th sample. This distribution is close to a normal distribution with standard deviation equal to 2.3. And this distribution reflects the expectations about how signal sources should be distributed. Distribution (2.3) will correspond to the following function $\varphi_j(y_{jk})$:

$$\varphi_{jk}(y_{jk}) = 1 - 2 \cdot \frac{1}{\left(1 + \exp\{s_{jk} - y_{jk}\}\right)}. \qquad (2.4)$$

Substituting this function in (2.2), we obtain an adaptive algorithm for finding the separation matrix witch takes into account a priori information about the signal.

III. CONCLUSIONS

An algorithm of blind separation using a priori information about the signal is derived. And experimental study of this algorithm is applied to the problem of extraction of fetal ECG from abdominal multichannel ECG. Separation algorithm witch use a priori information showed approximately 5-fold increase in signal to noise ratio for the separated fetal ECG signal compared with the algorithm witch does not use a priori information. The experimental data show that the use of a priori information about the source signals can significantly increase the quality of their separation.

REFERENCES

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