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Research on Influence of Source Number Estimation on Application of Blind Source Separation Algorithms

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Abstract

Source number estimation is the premise for applying blind source separation algorithms, and it's a technical difficulty. The influence of source number estimation on application of blind source separation algorithms is researched in present paper. Results show that, in the condition of over-determined and positive-determined , if the estimated source number is more than practical source number, then the separated signals would be more than practical source signals, usually all of the source signals can be separated, and the part of separated signals more than practical source signals would be the practical source signals' copy. When the estimated source number is less than that of practical source signals, the separated source signals would be part of the practical source signals. In the condition of under-determined, when estimated source number is more than practical source number, all columns of the practical mixing matrix can be estimated, and the other estimated columns are the practical columns' copy or redundancy, all of the practical source signals can be separated, and the other part are the practical source signals' copy or redundancy. If the estimated source number is less than that of practical source signals, part columns of the practical mixed matrix can be estimated, and part of the practical source signals can be recovered.

*Keywords:*Source number estimation; Blind source separation; Mixing matrix estimation; Source signals separation

1. Introduction

Blind source separation (BSS) is extracting the original source signals which can't be observed directly only from observed mixed signals[1]. Source number estimation is the premise and basis of applying blind source separation algorithms, and directly affects the application accuracy and stability.

Source number estimation has been a research hot and difficulty in the field of blind source separation for a long time[2]. In the condition of over-determined and positive- determined, source number estimation algorithms mainly include information theory methods, such as AIC, MDL, etc., SVD and Gail circle method[3], which usually require high signal to noise ratio, and when the number of antenna array is equal to that of source signals, the estimated source number is usually less than that of practical source signals. In the condition of under-determined, source number estimation is very difficult, and the estimation algorithms mainly include two kinds, one is based on source

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signals' sparsity, and when the sparsity of source signals can't satisfy the algorithms' requirements, the estimation effect would be poor. The other kind is based on observed signals' augmented, and the means mainly are wavelet analysis, experience modal analysis (EMD), and time delay method, but the estimation accuracy is low overall.

C. Xu et al. have carried out some research on the effect of source number estimation on applying over-determined and positive-determined blind source separation algorithms[4], but when the estimated source number is less than practical source number, the conclusions are not explicit, and there is no research on under-determined condition. In short, source number estimation for blind source separation algorithms has not been very efficiently solved, especially for under-determined condition. If the estimated source number is not consistent with the actual source number, how blind source separation algorithm results, which has been few studied by scholars.

In this article, the effect of source number estimation on applying blind source separation algorithms are further and comprehensively carried out by theoretical research. In the conditions of over-determined and positive-determined, the blind source separation algorithms separately based on natural gradient (NG)[5] and equivariant adaptive source separation via independence (EASI)[6] are implemented for signals separation experiment, which are used for analyzing the effect of source number estimation that is inconsistent with the practical source number. In the condition of under-determined, when the estimated source number is inconsistent with practical source number, the mixing matrix estimation algorithm based on time-frequency single source detection[7] is implemented for analyzing the effect of source number estimation on mixing matrix estimation, and statistics sparse decomposition algorithm[8] is used for analyzing the effect of source number estimation on source signals separation.

Nomenclature

EMD	experience modal analysis
NG	natural gradient
EASI	equivariant adaptive source separation via independence

2. Models of radiation source signals mixing and blind source separation

Supposing that the number of practical radiation source signals is n, and the signals are denoted as $\boldsymbol{s}(t)=[s_1(t),s_2(t),...,s_n(t)]^T \in R^{n\times T_0}$, in which T_0 is the sampling points. When the n radiation source signals are propagating and received by the sensors, they are bound to be mixed, and the received mixed signals are denoted as $\boldsymbol{x}(t)=[x_1(t),x_2(t),...,x_m(t)]^T \in R^{m\times T_0}$. Any observed signal is a linear combination of the radiation source signals. The linear Instantaneous combination model is

$$\boldsymbol{x}(t)=\boldsymbol{A}\boldsymbol{s}(t)+\boldsymbol{n}(t) \tag{1}$$

Where, the prior information of mixing matrix $\boldsymbol{A}\in R^{m\times n}$ and source signals $\boldsymbol{s}(t)$ can't be gotten, but only $\boldsymbol{x}(t)$ can be observed. Source number estimation means that estimating the number of source signals only based on the observed signals matrix, and the ultimate goal of blind source separation is to recover the source signals $\boldsymbol{s}(t)$ from the observed signals $\boldsymbol{x}(t)$.

Supposing the noise during receiving the mixed signals can be neglected, the separation equation is,

$$\boldsymbol{y}(t)=\boldsymbol{W}_{n\times m}\cdot \boldsymbol{x}(t) \tag{2}$$

In the formula (2), $\boldsymbol{W}$ is called the separation matrix, $\boldsymbol{y}(t)$ is the estimated source signals. From equation (2), it is known that, when the estimated source number is inconsistent with the practical source number, the dimensions of separating matrix $\boldsymbol{W}$ would be inconsistent with accurate separation matrix dimensions, the dimensions of separated signals $\boldsymbol{y}(t)$ gotten by equation (3) would be inconsistent with those of practical source signals $\boldsymbol{s}(t)$.