NEW CRITERIA FOR BLIND SOURCE SEPARATION USING SECOND-ORDER CYCLIC STATISTICS*

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Abstract. This paper addresses the problem of blind separation of cyclostationary sources. By using the cyclostationarity property of the source signals, new criteria based on second-order cyclic statistics (SOCS) are established, from which two algorithms for blind source separation are proposed. Compared with the existing higher-order statistics-based approaches, our new approach requires few data samples and does not impose any restrictions on the probability distributions of the source signals. Simulation results are given to demonstrate the effectiveness of this new approach.

Key words: Blind source separation, adaptive algorithm, second-order cyclic statistics, convergence analysis.

1. Introduction

In blind source separation the problem is how to recover independent sources given the sensor outputs in which the sources have been mixed in an unknown channel. This problem has become increasingly important in the signal and speech processing area due to the prospective application in speech recognition, telecommunications, and medical signal processing. To date, numerous approaches to this problem have been proposed and implemented [2], [3], [6], [7], [9], [12]–[15]. For example, the HJ network approach [6], [7] and YW method [15] recover the source signals via iterative algorithms based on some higher-order criteria, whereas FOBI [2], AMUSE [14], and EAMUSE [9] estimate the source signals via matrix transform techniques. Although these approaches are successful under certain assumed conditions, they have diverse limitations. To begin with, the

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approaches based on higher-order statistics (HOS) require a large number of data samples for the time-averaging estimation of HOS; in addition, restrictions on the probability distributions of the source signals are often imposed within the HOS-based algorithms. Although AMUSE and EAMUSE exploit second-order statistics (SOS) properties of the signals, they are very sensitive to the additive correlated and colored noises, and may fail to work when the source signals involved are white processes. Finally, the existing approaches are applicable, at least from the definitions of SOS and HOS, only for stationary source signals.

In practical applications, nonstationary processes are frequently encountered in radar, sonar, and communication systems. Recently, there has been an increased interest in nonstationary, especially cyclostationary, processes. Almost all man-made communication signals exhibit cyclostationarity [5], so there is a need to study the problem of blind separation of cyclostationary sources. It is pointed out that blind separation is a key first step toward blind co-channel estimation and equalization in communication systems.

In this paper, the problem of blind separation of cyclostationary sources is studied by using the cyclostationarity property of the signals. New criteria based upon second-order cyclic statistics (SOCS) of the measurements are established, from which two new algorithms for blind source separation are proposed: a deterministic algorithm and a stochastic algorithm. The asymptotic stability of the deterministic algorithm and the convergence property [10] of the stochastic algorithm are investigated. Because of the use of SOCS, the new algorithms do not impose any restrictions on the probability distributions of the source signals, and are applicable to any stationary, white or colored, correlated or uncorrelated, Gaussian or non-Gaussian noises case. Simulation examples are presented to compare the new approaches with the existing HOS-based approach.

2. Problem statement

In this paper, we consider the following model:

\[
x(n) = \mathbf{A}_0 \mathbf{s}_0(n) + \mathbf{w}(n)
\]

where

\[
x(n) = [x_1(n), x_2(n), \ldots, x_M(n)]^T \text{ is the observed data vector;}
\]

\[
\mathbf{s}_0(n) = [s_1(n), s_2(n), \ldots, s_M(n)]^T \text{ is the unknown source vector;}
\]

\[
\mathbf{w}(n) = [w_1(n), w_2(n), \ldots, w_M(n)]^T \text{ is the additive noise vector;}
\]

\[
\mathbf{A}_0 = [a_{ij}]_{i,j=1}^{M,M} \text{ is the unknown parameter matrix that characterizes the unknown medium or the channel.}
\]

The objective of blind source separation is to identify \( \mathbf{A}_0 \) and estimate \( \mathbf{s}_0(n) \) from \( x(n) \) only.