Chapter XLIII
Independent Component Analysis Algorithms in Wireless Communication Systems

Sargam Parmar
Ganpat University, India

Bhuvan Unhelkar
MethodScience.com & University of Western Sydney

ABSTRACT

In commercial cellular networks, like the systems based on direct sequence code division multiple access (DSCD-MA), many types of interferences can appear, starting from multi-user interference inside each sector in a cell to interoperator interference. Also unintentional jamming can be present due to co-existing systems at the same band, whereas intentional jamming arises mainly in military applications. Independent Component Analysis (ICA) use as an advanced pre-processing tool for blind suppression of interfering signals in direct sequence spread spectrum communication systems utilizing antenna arrays. The role of ICA is to provide an interference-mitigated signal to the conventional detection. Several ICA algorithms exist for performing Blind Source Separation (BSS). ICA has been used to extract interference signals, but very less literature is available on the performance, that is, how does it behave in communication environment? This needs an evaluation of its performance in communication environment. This chapter evaluates the performance of some major ICA algorithms like Bell and Sejnowski's infomax algorithm, Cardoso's Joint Approximate Diagonalization of Eigen matrices (JADE), Pearson-ICA, and Comon's algorithm in a communication blind source separation problem. Independent signals representing Sub-Gaussian, Super-Gaussian, and mix users, are generated and then mixed linearly to simulate communication signals. Separation performance of ICA algorithms is measured by performance index.

INTRODUCTION

Wireless communication networks and systems that are used for example, by mobile phone users, have an essential challenge in division of this common transmission medium among several users. A primary goal of communication system is to enable each user of the system to communicate reliably despite the fact that the other users occupy the same resources, possibly simultaneously. As the number of users in the system grows, it becomes necessary to improve the efficiency of these common communication resources. Various communication systems based on CDMA (Code Division Multiple Access) techniques have become popular, because they offer several advantages over the more traditional FDMA and TDMA schemes based on the use of nonoverlapping frequency or time slots assigned to each user. The capacity of CDMA based communication system is larger, and it degrades gradually with increasing number of simultaneous users who can be asynchronous. CDMA systems require more advanced signal processing methods, and correct reception of CDMA signals is more difficult because of several disturbing phenomena such as multipath propagation, possibly fading channels, various types of interferences, time delays, and different powers of users.

The most important use of a spread spectrum communication system is that of interference mitigation. In fact, a spread spectrum communication system has an inherent temporal interference mitigation capability. At times, however, the interference can be too strong, or the requirements for the link quality are more stringent, so that additional interference mitigation is needed. In a cellular network the interference originating from the neighboring cells, called inter-cell interference, is one of the reasons for the need for additional interference mitigation capability in a receiver. Independent Component Analysis (ICA) use as an advanced preprocessing tool for blind suppression of interfering jammer signals in direct sequence spread spectrum communication systems utilizing antenna arrays. The role of ICA is to provide a jammer-mitigated signal to the conventional detection.

Jutten and H´erault provided one of the first significant approaches to the problem of blind separation of instantaneous linear mixtures. Since then, many different approaches have been attempted by numerous researches using neural networks, artificial learning, higher order statistics, minimum mutual information, beam-forming and adaptive noise cancellation, each claiming various degrees of success. Attempts have to been made to compare the various algorithms for their convergence speed, computational load and accuracy. Several ICA algorithms exist for performing Blind Source Separation (BSS).

This chapter evaluates the performance of some major ICA algorithms like Bell and Sejnowski's infomax algorithm, Cardoso's joint approximate diagonalization of Eigen matrices (JADE), Pearson-ICA and Comon's algorithm in a blind source separation problem. The main aim of this chapter is to determine accuracy of the algorithms by measuring performance index. Performance index versus number of Super-Gaussian, sub-Gaussian and mix users have been considered for comparison.

ICA ALGORITHMS

Consider the classical ICA model with instantaneous mixing

$$\mathbf{x} = \mathbf{A}\mathbf{s} + \mathbf{n} \tag{1}$$

where the sources $\mathbf{s} = [s_1, s_2, ..., s_n]^T$ are mutually independent random variables and $\mathbf{A}_{nxn}$ is an unknown invertible mixing matrix and noise $\mathbf{n} = [n_1, n_2, ..., n_n]^T$. The goal is to find only from observations, $\mathbf{x}$, a matrix $\mathbf{W}$ such that the output

$$\mathbf{y} = \mathbf{W}\mathbf{x} \tag{2}$$

is an estimate of the possible scaled and permutated source vector*s*.

Several algorithms exits for blind source separation. This chapter describes the performance of some major ICA algorithms. This section presents a brief description of the respective approaches of the compared ICA algorithms.

JADE Algorithm

The JADE algorithm relies on second and fourth-order cumulants to separate the sources. SOS is used to obtain a whitening matrix $\mathbf{Z}$ from the sample covariances. To reduce the computational load, only the $\boldsymbol{n}$ most significant eigen pairs of fourth order cumulants obtained from the whitened process are joint diagonalized by unitary matrix $\mathbf{U}$. The separated matrix can be estimated as $\mathbf{U}^{\dagger}\,\mathbf{Z}$, where † represents pseudo