# Blind Separation of Time/Position Varying Mixtures

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**Abstract**

We address the fascinating open engineering problem of blindly separating time/position varying mixtures, and attempt to separate the sources from such mixtures without having prior information about the sources or the mixing system. Unlike studies concerning instantaneous or convolutive mixtures, we assume that the mixing system (medium) is changing in time/position. Attempts to solve this problem have mostly utilized, so far, online algorithms based on tracking the mixing system by methods previously developed for the instantaneous or convolutive mixtures. In contrast with these attempts, we develop a batch algorithm in the form of Staged Sparse Component Analysis (SSCA). Accordingly, we assume that the sources are either sparse or can be 'sparsified'. In the first stage we estimate the mixing system filters, based on the scatter plot of the sparse mixtures' data, using a proper grouping and curve/surface fitting. In the second stage, the mixing system is inverted, yielding the estimated sources. We use the SSCA approach for solving three types of mixtures: time/position varying instantaneous mixtures, single-path mixtures and multi-path mixtures. Real image mixtures and simulated mixtures are used to test our approach.

**Index Terms**

Blind Source Separation (BSS), Sparse Component Analysis (SCA), Time/Position Varying Mixing/Unmixing.

## I. Introduction

Extensive research has been devoted over the last two decades to the subject of blind source separation (BSS), especially in the form of independent component analysis (ICA). The research mainly focused on the stationary, instantaneous and convolutive theoretical aspects of the problem and on practical applications. In the relevant models, the sources are attenuated by a fixed factor, and/or filtered by a fixed filter prior to being mixed. The approaches and techniques, used for solving the BSS problem of stationary mixtures, can be roughly divided into two categories: ICA and sparse component analysis (SCA). ICA assumes that the sources are statistically independent and, therefore, utilizes separation cost functions based on the maximization of non-Gaussianity [1], negentropy [2], maximum likelihood [3], or minimization of the mutual information [4], [5], diagonalization of the cumulant tensor [6], non-linear decorrelation [7] and second order statistics [8]. Blind separation using SCA assumes that the sources are sparse or can be projected onto a space of sparse representations by using a proper transformation ('sparsification'). The sources need not be statistically independent, but one should be able to represent them differently in some domain (i.e. there are atoms in a dictionary or instances in time/position in which only one source is represented or active). This approach lends itself to a geometric interpretation of the mixing coefficients. The mixing matrix entries can thereby be retrieved from the scatter plot of the 'sparsified' mixtures [9].

In most real-life scenarios, the mixing system is not constant as in the instantaneous or convolutive model, but it is changing as a function of time or position. The attenuation of signals/images varies over time/positin thus creating time/positin varying instantaneous mixtures. The delay/shift or reverberation/blurring of a signal/image may also vary over time/position creating a time/position varying single/multi-path mixtures. Only few studies address this generalized BSS problem. Most of them use the ICA approach and assume a slow varying mixing system, thus, enabling the use of an adaptive version of the algorithms developed for the stationary cases. The very few batch algorithms which assume a

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