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Editorial

Independent component analysis and beyond

Independent component analysis (ICA) aims at extracting unknown hidden factors/components from multivariate data using only the assumption that the unknown factors are mutually independent. Since the introduction of ICA concepts in the early 1980s in the context of neural networks and array signal processing, many new successful algorithms have been proposed that are now well-established methods. Since then, diverse applications in telecommunications, biomedical data analysis, feature extraction, speech separation, time-series analysis and data mining have been reported.

Recently, exciting developments have moved the field towards more general source separation paradigms. In order to discuss these new directions, we organized a workshop with the title "ICA and beyond" as part of the "Neural Information Processing Systems" (NIPS) conference 2002 in Vancouver, Canada. This workshop was able to bring together an active community of researchers from various fields such as signal processing, machine learning, statistics and applications. Besides presenting the state of the art, open problems were also raised such as: what are the good applications for nonlinear blind source separation? Of high relevance especially for practitioners is the question whether estimated ICA components are meaningful or not, i.e. how can we assess the reliability of the ICA solution. Another direction is algorithms that cannot only identify one-dimensional ICA components but also multi-dimensional components like independent subspaces (dependent component analysis). Furthermore, new criteria and models based on Bayesian statistics have been presented.

This special section of the Signal Processing journal summarizes the workshop and makes these new developments and questions available to a broader audience by including a peer-reviewed selection of 7 papers which were presented at the workshop. Following is a summary of those contributions.

Three easy ways for separating nonlinear mixtures?
C. Jutten, M. Babaie-Zadeh, S. Hosseini

This paper focuses on the issue of the separability of nonlinear mixtures. It recalls a result by G. Darmois in 1951, showing that statistical independence, by itself, does not suffice for nonlinear source separation, contrary to what happens in the linear case. The paper then discusses three kinds of additional constraints that have been proposed to allow nonlinear source separation: mixture smoothness, structural constraints and prior information on the sources, showing that in some of these cases it is possible to guarantee the recovery of the mixed sources.

MISEP—linear and nonlinear ICA based on mutual information
L. Almeida

This paper presents one possible method for unmixing nonlinearly mixed independent sources, the MISEP method. The criterion used for separation is the well-known Infomax, in which maximizing the output entropy of the separating nonlinear system can be shown to minimize the mutual information of the extracted components and thus to perform nonlinear ICA. In MISEP, nonlinearities are implemented as multi-layered perceptrons, which are smooth mappings and give the required regularization making separation possible. Experimental results confirm the method's ability to perform both linear and nonlinear ICA with various source distributions.

Blind separation of sources that have spatiotemporal variance dependencies
A. Hyvarinen, J. Hurri

This paper deals with the separation of sources which are not completely independent. Previous

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contributions to this problem usually assume and estimate some parametric model for the dependencies among the sources. Hyvarinen and Hurri choose a different approach: by requiring that the dependencies between the sources are due to correlations between the variances of the sources and by assuming that those variances have correlations in time themselves, the authors are able to define a criterion which probably recovers the sources.

Injecting noise for analysing the stability of ICA components
S. Harmeling, F. Meinecke, K.-R. Müller

When applying ICA to real-world data, a very relevant problem is the reliability of the extracted independent components. In some cases, the exact independence assumption for the sources does not hold, yet the ICA algorithms will give estimates of the sources. This paper suggests a way to assess the reliability of ICA components, that can be easily applied to any ICA algorithm. It is based on adding noise to the estimated source signals and examining how this affects the demixing matrix. The true independent sources are less affected than the artificial sources produced by the algorithm. The experimental results on fetal ECG data are given.

Hierarchical models of variance sources
H. Valpola, M. Harva, J. Karhunen

This paper shows how the Bayesian variational learning technique can be used to jointly model variances and means, a task that is difficult for many other learning paradigms. For this, the authors introduce the so-called variance nodes that allow the creation of hierarchical models of means and variances. This is of great practical importance, since most real-world signals (e.g. biomedical data) have over the time-course a varying variance, as the experiment section shows.

Hierarchy, priors, and wavelets: structure & signal modelling using ICA
S. Roberts, E. Roussos, R. Choudrey

In this paper, ICA is considered as part of a more general hierarchical system in which the data is first preprocessed either by wavelet transformation or by Gaussian kernel functions. In these constrained cases, ICA can be used either for sparse coding or unsupervised clustering. The technique used in the paper is variational Bayesian learning, which has the advantage of taking the constraints such as positivity into account by suitable priors. Also, the number of components can be solved in a natural way. The paper further presents some experiments with toy and real data.

Development of a flexible, realistic hearing in noise test environment (R-HINT-E)
L. Trainor, R. Sonnadara, K. Wiklund, J. Bondy, S. Gupta, S. Becker, I. Bruce, S. Haykin

This paper presents the authors' work on the development of a system that can produce test cases for the development of algorithms for new hearing aids that are able to combine information from several microphones. The authors thoroughly motivate the creation of such a database and give a summary of the previous work on this topic. The system consists of a large database of sentences spoken by different speakers and of different impulse functions characterizing room responses for various speaker/microphone configurations and different reverberation characteristics. Test cases can be easily created by convolving the sentences with the impulse functions.

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