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Guest Editorial

Latent variable analysis and signal separation

Independent component analysis (ICA) has been at the core of a rapidly evolving and very active area of research since the 1980s. While ICA and its most visible application, blind signal separation, are now mature and have become mainstream topics in signal and image processing, new approaches have emerged to solve a flurry of new problems involving nonlinear signal mixtures or various emerging types of latent variables, semi-blind models, and matrix or tensor decompositions.

It is often ignored that signals and datasets collected in scientific, engineering, medical, and social applications are often *combinations* of underlying data (so called *latent variables*). If such datasets can first be separated into the components that underlie them, we might expect that the quality of the models will improve significantly. ICA or matrix decompositions for instance use the relationships among large amounts of data and the probable relationships between the components to do this kind of separation. Each decomposition makes a different assumption about what the underlying structure in the data might be, so choosing the appropriate one is a critical choice in each application domain. Fortunately once this choice is made, most separation methods have few other parameters to set.

The LVA/ICA 2010 conference, which took place in Saint-Malo, France, from September 27 to 30, 2010, gathered the leading world experts in Latent Variable Analysis (LVA) and Signal Separation to present and discuss the latest developments in the field. This special issue gives an overview of current developments in the field with a selection of articles related to the theory of LVA and its applications to audio and biomedical data.

Classical ICA consists of a linear mixture model defined over the real or complex field and is typically solved using algorithms based on second- or higher-order statistics, whose performance is analyzed under ideal conditions such as infinite sample-size noiseless observations. The first four articles of this special issue deal with interesting departures from the classical ICA setting. Reyhani et al. examine the robustness of separation estimates when the ideal ICA assumptions are not fulfilled, and prove the consistency and asymptotic normality of the popular FastICA algorithm and its bootstrapped version. Zarzoso et al. develop a novel cost-effective solution to ICA based on conditional first-order statistics and study the impact of imperfect estimates of the prior information required to compute this solution. Although the nonlinear case is particularly difficult under the source independence assumption, Deville shows the separability of a special class of nonlinear mixtures with reference signals. This setting can be considered as the extension of the classical adaptive noise canceling approach and finds application in quantum information processing. Finally, Gutch et al. formulate ICA in arbitrary finite fields, developing separability conditions and some practical algorithms to perform independent source separation in such scenarios.

The following four papers investigate important issues related to signal separation techniques that extend ICA to partially dependent data. A first line is illustrated by the papers by Itahashi and by Anderson et al., whose primary focus is independent vector analysis (IVA), where dependencies exist across sources: Itahashi's work is dedicated to new stability conditions beyond traditional second-order criteria, while Anderson et al. propose a new IVA implementation to achieve multiset canonical correlation analysis, with a special emphasis on complex-valued sources. On a different line, the papers by Yeredor and by Santana et al. propose to exploit possible temporal structures of each source. Yeredor develops a general statistical framework for the separation of mixture of sources with general covariance structure, based on multiple snapshots. Santana et al. exploit the temporal behavior of higher-order statistics of a target signal to extract it blindly from a mixture, without seeking the global separation of all sources.

Another strong trend of research is the use of deterministic or probabilistic constraints about the sources and the channel. Niazadeh et al. estimate the channel under a sparsity assumption implemented via a smoothed ℓ_0 norm, while Driesen and Van Hamme exploit the nonnegativity of the sources together with cross-validation for the selection of the relevant sources in the context of nonnegative matrix factorization. On a more general line, Yilmaz and Cemgil provide a unified probabilistic framework for latent tensor factorization relying on different possible prior probability distributions for the sources.

The final part of this special issue is devoted to applications of latent variable analysis and signal separation.

Traditionally, audio and biomedical signal processing have played a leading role which remains central today. Vincent et al. summarize the outcomes of the four audio and biomedical Signal Separation Evaluation Campaigns conducted between 2007 to 2010 and point out the advances and the remaining challenges in these fields. On a similar line, Blandin et al. provide a large-scale comparison of angular spectrum-based and clustering-based method for multiple source localization. One essential research trend in the last five years concerns the design of advanced algorithms combining multiple source models and making it possible to exploit prior knowledge about the sources. This is illustrated by the articles of Wang et al. and Arberet et al., which present new algorithms to exploit biological knowledge constraints or spectral source models for gene transcriptional regulatory network inference and audio source separation, respectively. Another trend is the recent interest for real-world audio source separation problems pushed by the industry. Liu et al. present a convolutive audio source separation algorithm exploiting the facial information contained in audiovisual speech recordings, while Liutkus et al. introduce a new interactive audio format based on the embedding of data in the audio stream at the production stage allowing its separation and remixing at the decoding stage.

As Guest Editors, we would like to thank Professors Bjorn Ottersten and the Editor Wei Zhao for providing the opportunity to prepare this special issue. We also thank all the authors and the reviewers for their hard work. We hope this special issue will stimulate further research into the exciting field of LVA and signal separation.

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