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Advances in Subspace-Based Techniques for Signal Processing and Communications

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Editorial

Advances in Subspace-Based Techniques for Signal Processing and Communications

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Research in subspace-based techniques for signal processing was initiated more than three decades ago, and there has been considerable progress in the area. Thorough studies have shown that the estimation and detection tasks in many signal processing and communications applications can be significantly improved by using the subspace-based methodology. Over the past few years new potential applications have emerged, and subspace methods have been adopted in several diverse fields such as smart antennas, sensor arrays, multiuser detection, system identification, time delay estimation, blind channel estimation, image segmentation, speech enhancement, learning systems, magnetic resonance spectroscopy, and radar systems. Subspace-based methods not only provide new insight into many such problems, but they also offer a good tradeoff between achieved performance and computational complexity. In most cases they can be considered to be low-cost alternatives to computationally intensive maximum-likelihood approaches. The interest of the signal processing community in subspace-based schemes remains strong as it is evident from the numerous articles and reports published in this area each year as well as from the attention that attracted the current special issue.

The original goal of this special issue was to present state-of-the-art subspace techniques for modern signal processing applications and to address theoretical and implementation issues concerning this useful methodology. Judging from the contents of the issue and the high-quality papers it comprises, we believe that the goal has been reached. The special issue gathers eleven papers and exhibits a balance between theoretical results and application-oriented developments.

Although it is difficult to draw a line, we can distinguish two clusters of papers in this issue. The first cluster consists of six articles that are concerned with theoretical problems encountered in the subspace approach, while the second comprises five papers whose developments are related to specific application problems (communications, imaging, and speech).

In the first cluster, the paper by M. Basseville et al. provides a review of theoretical and practical aspects of output-only covariance-driven subspace-based identification and detection algorithms. The proposed techniques target problems in structural analysis and monitoring of mechanical, civil, and aeronautic structures.

The article by K. G. Oweiss and D. J. Anderson deals with blind separation of nonstationary correlated signal sources contaminated by additive correlated noise impinging on a sensor array. Such situations arise in many classical and modern applications. The authors in this work apply their technique to the problem of recording neuronal ensembles in the brain, using microelectrode arrays.

The third paper by S. C. Douglas proposes an adaptive scheme for imposing paraunitary constraints on a multi-channel linear system. The corresponding procedure has a simple computational structure and exhibits improved convergence properties as compared to conventional gradient-type subspace adaptive methods. The technique can be extended to higher-dimensional data sets and used for different tasks such as image sequence coding.

In the paper by A. Quinlan et al. a novel model order selection method of low complexity is developed. The

proposed technique is based on the observation that the eigenvalues corresponding to the noise subspace follow an exponential profile. As opposed to traditional schemes, the order selection test developed in this paper performs well when the number of available data (or snapshots) is small.

The work by E. A. Marengo and F. K. Gruber addresses the problem of inverse scattering of point targets embedded in a known medium. Assuming availability of the multistatic response matrix, a signal subspace methodology is used for estimating the locations and scattering strengths of targets. The proposed technique exhibits improved target localization as compared to existing schemes.

In the sixth—and last—paper of the first group, by M. I. Y. Williams et al. a new versatile broadband beamformer is proposed. For any set of space-time sampling positions the authors are capable of selecting the pattern that exhibits the smallest mean-squared error with respect to the desired one, by using a modal subspace decomposition method. The proposed technique is applicable to both sparse and dense arrays, with nonuniform and asynchronous time sampling, and to dynamic arrays with moving sensors. Such broadband beamformers may be used, among other applications, in wireless communications, sonar, and sensor networks.

The second set of articles contains two papers dealing with problems in communication systems. First, the work by M. Chen et al. is concerned with long-range prediction of wireless communication channels. Adopting a stochastic sinusoidal representation of a Rayleigh fading channel, new predictors are developed that outperform the existing ones in the case of suburban environments. The main part of the proposed techniques relies on a subspace-based model selection method. The second paper by K. Zarifi and A. B. Gershman offers a comparative study of two popular blind subspace-based signature estimation algorithms for DS-CDMA systems in an unknown correlated noise environment. The theoretical analysis reveals how the performance of these techniques depends on the environmental parameters and quantifies the discrepancy introduced by the conventional white noise assumption analysis.

The second group of articles also contains a paper by H. Kwon and N. M. Nasrabadi that performs a comparative study of various subspace-filter-based detection algorithms in the context of hyperspectral imagery. The authors first derive nonlinear versions of a number of well-known linear matched-filter detectors and then apply both, their linear and nonlinear versions to synthetic and real hyperspectral images. As it is often the case in image processing, the nonlinear techniques outperform their linear counterparts.

The last two articles are concerned with speech processing. More specifically the work by K. Hermus et al. presents a review of subspace-based speech enhancement techniques as well as analytic upper bounds for their performance. Also, the applicability of these techniques to automatic speech recognition is investigated. Finally, the paper by U. Guz et al. proposes a new procedure for modeling speech signals based on the so-called predefined signature functions and envelope sets which are speaker and language independent. The signature functions are obtained by using principal component

analysis and the new method is experimentally tested in the context of speech coding.

We would like to thank all the authors who submitted papers to this special issue and the many colleagues who took part in the review process. The efforts of the reviewers and their constructive criticism and remarks have led to considerable improvements of the papers and the overall quality of the issue. We also appreciate the efforts of both the authors of the included papers and the reviewers to comply with the submission and revision timeline. Finally, we would like to thank the Editorial Office of EURASIP JASP and the Professors M. Moonen and A. H. Sayed (the former and current Editor-in-Chief, resp.) for their continuous and valuable support.

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