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Signal Processing 84 (2004) 2461–2463

**SIGNAL
PROCESSING**

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Call for papers

Tensor Signal Processing

Scope

Tensors arise in multiple areas of mathematics, science and technology. For example, in the physics of continuous media, tensor quantities arise in constitutive equations that are used to describe charge, mass, momentum and energy transport (the diffusion tensor, the electrical conductivity tensor, the thermal conductivity tensor, etc.). In fact, any non-trivial presentation of most theories of Physics resorts to tensor formulations. This is true for most of the theoretical branches, such as Quantum and Relativistic Mechanics, and for those with a direct impact on Engineering, such as Continuum and Statistical Mechanics, Thermodynamics, and Electromagnetism.

Hence tensor analysis is a well-established branch of mathematics that is used extensively in many areas of science and engineering. Nevertheless tensor formulations are not usual in Signal Processing and related fields, though, for specific scenarios, they should be of major interest. This could be partly due to the fact that signal processors have found a way around second-order tensors by using symbolic matrix notation as an invariant representation of, for example, linear operators, expectations of dyadic products (correlation matrices) and derivatives of vector functions (Jacobian matrices). Possibly the most referenced operation is the *Kronecker Tensor Product* in which all the components of two arrays are multiplied or, equivalently, a higher dimensional signal is obtained from two lower

dimensional ones. This is customarily used to obtain a multidimensional separable basis. A systematic use of tensor concepts in Signal Processing has been motivated by the field of Higher Order Statistics (HOS), since the basic HOS entities—higher order moments and cumulants—are higher order tensors. The mathematical framework is based on Multilinear Algebra, i.e., the generalisation to higher order tensors of Matrix Algebra. Interesting advances have been reported using this framework in Blind Identification and Blind Source Separation, based on recent research on the extension of the Singular Value Decomposition (SVD) and related algebraic approaches, such as Principal Component Analysis (PCA) and the Independent Component Analysis (ICA).

The use of tensor data in Signal Processing has been mostly applied to scalar data, where tensors describe some properties of the data field. For example, tensors have been used in Signal Processing and Computer Vision to represent spatio-temporal features (the so-called structure tensor) that adaptively control the behaviour of algorithms such as motion and salient feature detection and camera calibration.

Even though many experiments and techniques measure genuine tensors, they have not been traditionally included in the areas of interest of Signal Processing. Nevertheless in the last few years, in the fields of Signal Processing and Computer Vision, there has been an increased interest in developing methods for tensor valued data, mainly boosted by a new medical imaging

modality referred to as Diffusion Tensor Magnetic Resonance Imaging (DT-MRI) and the need to process and visualise such tensor images. Today various sensing modalities provide tensor data, usually arranged in (possibly irregularly) sampled multidimensional signals, and none of these measurements are fully reliable since any real sensor will provide noisy and possibly incomplete and degraded data. Therefore, all problems dealt with in conventional Signal Processing—such as filtering, restoration/reconstruction, classification, etc.—must also be addressed when dealing with uncertain second- and higher-order tensor signals.

Despite promising advances emerging from the processing of DT-MRI and other tensor data in different applications, tensor signal processing is still in its infancy since current approaches to processing tensor data mostly disregard both their essential stochastic and tensor natures. In fact, no probability theory on tensor-variate random variables and fields is currently available and most processing schemes just consider tensors as conventional multichannel data by stacking the tensor components. Therefore tensor data processing is commonly approached as a specific case of multichannel signal processing while it should be the opposite, i.e., multichannel signal processing is a particular case of tensor signal processing. This common approach implies ignoring information that should be accounted for during the whole processing procedure, as tensors are much more general structures than vectors, and writing tensor signals as a succession of vectors fails to preserve intrinsic algebraic relationships. Using conventional multichannel signal processing to process tensor signals will be suboptimal if the algebraic and probabilistic relations among the components are not properly accounted for.

The goal of this special issue is to bring together theoretical and experimental results that reflect the recent advances in tensor signal processing as well as open new avenues for research in the field.

Relevant themes include (but are not limited to)

- Multilinear algebra and tensor formulations for signal processing.
- Representation of spatio-temporal features using tensors.
- Acquisition and reconstruction of genuine tensor data.
- Tensor-variate random variables and fields and statistical inference.
- Information theoretic methods on tensor data.
- Statistical tensor signal processing.
- PDE and variational approaches to tensor signal processing.
- Tensor data processing (enhancement, segmentation, registration,...).
- Applications of tensor signal processing (especially in those areas where tensor data are measured).

Schedule

Deadline for manuscript submission: March 1, 2005

Notification of acceptance: September 1, 2005

Publication date: approx. December 2005

Submission guidelines

The manuscript format must follow the Signal Processing Journal rules. Manuscripts have to be submitted electronically using the word TensorSP as the e-mail subject (please, be sure to include exactly this e-mail subject) to Profs. Juan Ruiz-Alzola and Carl-Fredrik Westin (please, copy both) in PDF format. Manuscripts should be self-contained and not exceed 30 double-spaced pages typed in 10 points or larger. The first page must contain the title, the complete author addresses, an abstract of 500 words and a list of keywords.

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