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Sparsity in array processing: methods and performances

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SPECIAL SESSION PROPOSAL

THE EIGHTH IEEE SENSOR ARRAY AND MULTICHANNEL SIGNAL PROCESSING WORKSHOP (SAM 2014)

November, 23th, 2013

Session title : Sparsity in array processing: methods and performances

Rationale and outline :

In the last few years, we witnessed to an extraordinary and still growing development of sparse signal recovery in a wide number of applicative contexts such as communications, biomedicine, radar, microwave imaging, source localization, astronomy, seismology... In many realistic array processing applications, the sparsity nature underlying various signals/arrays has to be exploited in recovery algorithms to enhance their performances. In this special session, most recent results in estimators based on sparsity-promoting criteria is proposed for near-field source estimation [1], coprime arrays [5], very large arrays in a decentralized architecture [3], dynamic dictionary design [4,6] and in their optimal performances [2]. In particular, a major challenge common to most of the proposed contributions in this special session is the so-called « off-grid problem ». It is important to propose innovative solutions to mitigate the estimation bias for signal parameters which do not belong to the predefined grid commonly used in standard sparse estimators (as for instance LASSO, Basis and Matching Pursuits, ...). The aim of this special session is to promote the exchanges between several major actors of the Array and Multichannel Processing community around the world as for instance Delft University (Nederland), LSS and SATIE Labs (France), Aalborg University (Denmark), University of California San Diego (USA), Nice Sophia-Antipolis University (France), Washington University (USA), Minnesota University (USA). A last contribution from Professor Magnus Jansson (KTH) could be integrated to this session.

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List of committed contributors :

1. **Title:** Sparsity-aware Joint DOA Estimation and Ranging of Multiple Near-field Sources

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Scope/ Abstract: Near-field source localization is an important aspect in many diverse areas such as acoustics, seismology, to list a few. The planar wave assumption frequently used in far-field source localization is no longer valid when the sources are in near-field. Near-field sources can be localized by solving a joint direction-of-arrival and range estimation problem. The original multiple near-field source localization is a multi-dimensional non-linear optimization problem which is computationally intractable. In this paper, using a 2D grid-based model and by further leveraging on the sparsity we can solve the aforementioned problem efficiently using any of the off-the-shelf ℓ_1 -norm optimization solvers. Exploiting the cross-correlations among the sensors, we can significantly reduce the complexity by solving two sparse reconstruction problems of lower dimensions instead of a single sparse reconstruction problem of a higher dimension.

2. **Title :** Bayesian performance analysis for dictionary based sparse source localization

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Scope/ Abstract : Sparse reconstruction has been investigated recently as a novel method for direction of arrival estimation. However, this type of estimators are always biased since the set of possible solutions lies in a discrete dictionary. In this work we derive the BMSE for the sparse on-grid estimator and relate it to the coherence of the sensing matrix. The coherence being related to the sparsity level required to assure the results of an ℓ_1 based optimization, we link the quality of the estimation with the number of sources, the number of antennas and the size of the dictionary.

3. **Title :** Distributed image reconstruction for very large arrays in radio astronomy

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Scope/ Abstract : Future radiointerferometric arrays are characterized by a paradox. Their large number of receptors (up to millions for SKA) allow theoretically unprecedented imaging resolution. In the same time, the ultramassive amount of

samples makes the data transfer and computational load orders of magnitude too high for any currently existing image reconstruction algorithm to achieve, or even approach, the theoretical resolution. State-of-the-art reconstruction algorithms are based on sparsity-promoting criteria. We investigate here the possibility to decentralize such algorithms to reduce the amount of transferred data. The loss in MSE incurred by the proposed approach is evaluated theoretically and numerically.

4. **Title:** Sparse Signal Estimation Using Dynamic Dictionary-Based Methods

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Scope/ Abstract. The article concerns sparse signal estimation, for example in a compressed sensing context, when the basis vectors are specified by unknown continuous parameters. An example could be estimating the model order, frequencies and amplitudes of a superposition of complex sinusoids; this problem is encountered in many areas, such as spectral estimation and direction of arrival estimation. Given that the signal cannot have a sparse representation in a finite discrete dictionary, the common approach is to reduce the continuous parameter space to a fixed grid of points. However, discretization leads to a mismatch between the assumed and the actual bases. The approximation can be improved by using a finer grid, the penalty being increased complexity and dictionary coherence. In this work, we propose and analyze new methods that dynamically adjust the dictionary over the iterations to overcome the basis mismatch issues.

5. **Title:** Super Resolution for Direction of Arrival Estimation with Coprime Arrays

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Scope/ Abstract : In this paper we consider the problem of direction of arrival (DOA) estimation using sparsity enforced reconstruction methods. Coprime arrays with $M+N$ sensors are utilized to increase the degree of freedom from $O(M+N)$ to $O(MN)$. The key to the success of sparsity based DOA estimation relies on the assumption that every target must fall on the predefined grid. Off-grid targets can highly jeopardize the reconstruction performance. In this paper, we implement the continuous sparse recovery method, which considers every possible locations in the

region, to solve this difficulty. We analyze the robustness of this method when time samples are limited. By numerical examples, we show that the proposed method outperforms both MUSIC and traditional discrete sparse recovery method.

6. Title: Off-grid Directions-of-Arrival Estimation by Learning Sparse Dictionaries for Sparse Spatial Spectra

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Scope/ Abstract : A major limitation of most methods exploiting sparse signal or spectral models for the purpose of estimating directions-of-arrival stems from the fixed model dictionary that is formed from array response vectors over a discrete search grid of possible directions. In general the array responses to actual DoAs will most likely not be members of such a dictionary. In this work, the sparse spectral signal model with uncertainty of linearized dictionary parameter mismatch is considered, and the dictionary matrix is reformulated into a multiplication of a fixed base dictionary and a sparse matrix. Based on this double-sparsity model, an alternating dictionary learning-sparse spectral model fitting approach is proposed to improve the estimation error of DoAs and their powers. The performance of the proposed method is demonstrated by numerical simulations.