Post-doctoral proposal

High dimensional inverse problems in acoustical imaging

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Starting date: before december 2022
Duration: 12 months
Gross Salary: 3200 € monthly
Profile: signal processing, optimization, data science, knowledge of Matlab or Scipy.
Knowledge of inverse problem or acoustics is appreciated but not necessary.

Context

Acoustical imaging aims at characterizing acoustical scenes, in order to localize sources and estimate their powers. Prior art on the subject is concerned with improvements in spatial resolution and dynamics. Other parameters can be estimated beyond these two fundamental parameters using advanced signal processing methods. Estimation of the correlation between sources or estimation of their directivity, etc., yield information about their physical nature. When source are controlled and known, information about the propagation environment are obtained. Another problem of interest is the capture of acoustical field in a volume with a limited number of sensors. In most methods, a simple physical model is assumed to describe the direct problem, and formulate an inverse problem, with input data gathered on a microphone array.

Inverse problems in acoustics involves high dimensional numerical problems, due to the increasing size of the regions of interest, but also because of the increasing complexity of the source models (estimation of the directivity of the sources, of correlations between sources, etc.) or soundfields (high frequencies, scatterers, etc.). Moreover, experimental conditions are usually imperfectly known (microphone array and propagation of acoustical waves), implying model errors.

As a specific example, recent works [1-4] of our team have shown that large scale source localization is tractable with appropriate algorithms. In [2], the DAMAS algorithm is revisited, shown to solve the Covariance Matrix Fitting problem, and a new efficient algorithm is proposed.

In [3], low-rank and sparsity based methods are used to estimate jointly the positions of the sources and their mutual correlations, a high dimensional problem. Usage of the Orthogonal Least Squares algorithm allows estimation of a covariance matrix in linear time with respect to the size of the grid.

In [1], a method for gridless source localization is proposed, avoiding the discretization of space. In all three cases, the computational complexity of the methods was reduced by several orders of magnitude compared to the state of the art, allowing application to large domains, e.g. 3D domains.

This kind of problems have multiples applications : in room acoustics, correlated sources can help identifying multiples paths and Green functions, which characterize the propagation medium. Characterization of aeroacoustical noise due to airflow around a vehicle (car, train, plan) also raises the interest of the transport industry, aiming at improving the acoustic comfort of passengers and neighboring communities. In audible acoustics, speech processing or propagation in urban environments can also be cited. In ultrasonics, localization of objects in a submarine waveguide, or medical imaging are potential applications.

Goals

Inverse problems involving high dimensions are frequent in acoustic imaging:

- large microphone arrays, distributed in a large spatial domain (high dimensional data)
- large region of interest (e.g., 3D domain, or fine discretization of the space)
- complex sources, with uneven directivity, described by their spread [5], or as the linear combination of elementary sources, involving model order estimation problems [6],
- estimation of spatial covariance matrices, or temporal characteristic of the sources.
- capture of soundfields at high frequencies
- When applicable, continuous sparsity will be considered to solve these problems [1,7].

Most of the standard methods are not able to deals with such problems either because their computational cost is too high, because they are inaccurate or because they are not designed to estimate additional parameters of complex sources.

The goal of the project is thus the design, the theoretical analysis and validation of numerical methods for high dimensional acoustical inverse problems. Problems of interest include:

- localization of correlated sources: analysis of the algorithm used in [3], and application to echo identification in a reverberant room to estimate its shape [8],
- quantification of the uncertainties caused by inexact knowledge of the propagation environment [9]
- calibration of microphone arrays, i.e. learning of the acoustical model to be used, e.g. in a room of unknown acoustical properties [10].
- efficient modeling and capture of acoustical fields.

The developed methods will be validated on real acoustical data.

The specific problems that will be considered will be chosen in collaboration with the recruited postdoc.

Bibliography

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