Thesis subject 2021

Laboratory: Institut Jean le Rond d’Alembert
University: Sorbonne Université

Title of the thesis:
Problèmes inverses acoustiques en grande dimension
High dimensional acoustical inverse problems

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Collaborations within the thesis: L2S

Program affiliation:
Cotutelle:
University:

This subject can be published on the doctoral school’s web site: yes

Thesis’s summary (abstract):
In the context of inverse problems for the characterization of acoustic sources, recent work [1-2] has shown the interest of sparse low-rank methods to locate and estimate the spatial covariance matrix of the signals emitted. The objective of the thesis is to exploit its potential by the design, study, and experimental validation of methods for acoustic inverse problems in large dimensions. These principles find applications in many fields. In room acoustics, in particular, they can be associated with the image source model to identify the multiple paths and Green's functions that determine the acoustic environment. The characterization of aeroacoustic noise linked to the flow of air on vehicles (car, train, plane, etc.) is also arousing growing interest in the transport industry, which seeks to improve the acoustic comfort of passengers and residents. In the audible field, we can also cite speech processing or the characterization of propagation in the urban environment.
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 informations about their physical nature. When source are controlled and known, informations about the propagation environment are obtained. 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.). Moreover, experimental conditions are usually imperfectly known (microphone array and propagation of acoustical waves), implying model errors.

In this context, recent works [1-2] have shown that low-rank and sparsity based methods can 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, allowing application to high dimensional problems. In room acoustics, correlated sources can help identifying multiples paths and Green functions, which characterize the propagation medium. Charaterization 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 neighbouring 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

The goal of the PhD project is the design, analysis and experimental validation of numerical methods for high dimensional acoustical inverse problems. Settings involving high dimensions are frequent in acoustical 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 [3], or as the linear combination of elementary sources, involving model order estimation problems [4],
- estimation of spatial covariance matrices, or temporal characteristic of the sources.
- When applicable, continuous sparsity will be considered to solve these problems [5].

Problems of interest include:
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- Localization of correlated sources: analysis of the algorithm used in [1], and application to echo identification in a reverberant room to estimate its shape [6],
- quantification of the uncertainties caused by inexact knowledge of the propagation environment [7]
- calibration of microphone arrays, i.e. learning of the acoustical model to be used, e.g. in a room of unknown acoustical properties [8].

Bibliographie