SMART WAVES

PSL UNIVERSITÉ PARIS

PhD proposal

Title: Matrix imaging and inverse problem: from ultrasonic medical to marine acoustic imaging

Supervisors:

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Context:

The "Smart Waves" program funded by the PSL University (Paris Sciences et Lettres) aims to bring together complementary scientific approaches, in this case focusing on acoustic imaging at different scales: "ultrasound" with medical applications, "acoustics" with environmental applications, and "low-frequency acoustics" with seismological applications. These themes are being pursued by the Institut Langevin (ESPCI), the Centre de Géosciences at Mines Paris and the Geology Laboratory at ENS Ulm, respectively.

Subject:

Ultrasonic imaging involves the analysis of acoustic or elastic waves at frequencies ranging from 1 to 40 MHz. The main applications are in medical imaging and non-destructive testing, typically for centimeter depths of investigation and millimeter resolution. Acoustic imaging, on the other hand, aims to map the sea bed and the first few kilometers of the subsurface, with an expected resolution of ten meters (typical frequencies between 10 and several hundred 100 Hz). The aim of this thesis is to compare recent advances in the two fields and see whether they can be transposed.

Without being exhaustive, here are challenges that should be explored in greater depth:

- Ultrasound imaging is concerned with scattering media generating an ultrasound "speckle" induced by a random distribution of sub-resolved scatters. Recently, the concept of "matrix imaging" has been developed to exploit this speckle and correct, in post-processing, the problems of aberrations and reverberations that generally pollute ultrasonic imaging (Bureau, 2003). Marine

acoustic imagery is often faced with more deterministic multi-layer environments (specular reflection). However, faulted zones with high contrasts imply multiple diffraction phenomena. The first objective is therefore to see whether the matrix approach can be successfully applied to these problems in marine acoustics;

- Furthermore, under the assumption of simple diffraction, recent progress has been made in acoustic imaging with the derivation of a quantitative imaging operator (approximate inverse, Chauris and Cocher, 2017; Chauris and Farshad, 2023) which provides much better resolution than standard (adjoint) imaging operators. It will be interesting to see whether the inverse operator can be applied in the ultrasonic speckle regime;
- Acoustic marine imaging considers both disturbances in the velocity and density of the medium and the possible coupling between these two parameters, whereas ultrasound imagery is only qualitative and is designed to image the reflectivity of the medium. The ability to image sound velocity and density fluctuations independently in ultrasound imaging would be a real breakthrough;
- In both fields, focusing the areas to be imaged offers a possibility to improve the quality of the macro-model controlling the wave propagation. Here again, the techniques are different (matrix approaches, for example, for ultrasound imagery, Lambert, 2020; and speed analysis by migration for marine acoustic imaging);

In addition to a theoretical comparison of approaches, the aim is also to apply these recent advances to data sets typical of each field. For ultrasound imaging, this will involve data from ultrasound phantoms mimicking the acoustic properties of tissues, followed by in-vivo data from the liver, breast and brain (transcranial imaging). For acoustic marine imaging, the case could be the Nankai Trough off the coast of Japan, with complex structures in the first few hundred meters below the subsurface.

Profile

The candidate should have a solid background in mathematics and physics, with a taste for medical or geophysical applications. Experience in computer programming is also important. The candidate must be fluent in written and spoken English

How to apply:

Please send (in pdf format) to herve.chauris@minesparis.psl.eu before 8 April 2025:

- Resume

- Cover letter

- Copies of diplomas and transcripts

- Letters of recommendation or the name of one or two people to contact

- If possible, a report on a Master 1 or Master 2 internship or an engineering internship.

References:

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