Post-doc fellowship : High resolution Image reconstruction for passive ultrasound imaging of cavitation

General context:

This 24-month postdoc, available from November 2023, is funded by an ANR grant gathering three research groups in computational medical imaging from the University of Toulouse (IRIT lab, Prof. Denis Kouamé) the University of Lyon (CREATIS lab, PI Prof. Adrian Basarab) and Laboratory of Therapeutic Applications of Ultrasound, LabTAU (PI Dr Bruno Gilles). The postdoc will take place in Toulouse, IRIT, in close collaboration with Prof. A. Basarab and Dr B. Gilles from the University of Lyon (regular meetings, visits to Lyon).

Presentation and objectives

The main objectives of this post-doc fellowship is to develop both model-based and learning techniques for medical image restoration with application to passive acoustic mapping.

Therapeutic ultrasound offers great perspectives for minimally-invasive surgery, enhanced drug delivery or cancer immunotherapy. It now addresses a very broad range of indications from prostate or brain tumors, to glaucoma. Among other mechanisms, a number of emerging applications rely on the phenomenon of ultrasound cavitation, which represents the oscillation of ultrasound-induced microbubbles. In any of these applications, monitoring the treatment in real-time is a required step for potential clinical applications.

While active ultrasound B-mode imaging is well suited to monitor thermal or mechanical permanent alteration of tissues, the microbubble activity – being directly activated by high intensity ultrasound – cannot be characterized in real-time using an active ultrasound scanner because of dazzling effects. To localize and quantify cavitation activity, Passive Acoustic Mapping (PAM) techniques have been developed [1-5]. To localize cavitation activity, PAM uses beamforming algorithms on signals passively received by an array of transducers during HIFU emission [1,2]. A major limitation of such passive methods is that, as opposed to active imaging, there is no emission time to refer to, and the mapping only results from the coherent summation of time-delayed wavefronts over the aperture of the receiving array.

When commercial echographic arrays are used, this results into poor axial resolutions. This aspect is even more critical for applications requiring a 3D monitoring of the cavitation activity, due to very low apertures of conventional matrix arrays, the only solution being then to make use of complex arrays specifically designed for a given application, which limits the pertinence of such 3D passive imaging techniques.

We have developed many techniques for beamforming and for ultrasound image restoration, *e.g* [6-8]. Based on that, we aim at improving the 3D-PAM through adaptive imaging and deconvolution methods to obtain a millimetric resolution in any direction.
The objective of the post-doc work is to enhance mapping resolution (deconvolution, reconstruction) via combination of model-based and learning-based approaches. Thus, first a forward model based on PAM will be developed and inverted using dedicated regularization.

Then, deep learning-based approaches will be considered based on the acquired data with a special focus on unsupervised learning. In addition, a simulation dataset will also be developed.

Co-supervision:

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Applicant profile:

We are searching for interested candidates with strong background in at least one of the following fields: inverse problems, optimization and optimal control, machine learning. Interest in medical imaging and in particular in ultrasound imaging is appreciated.

Application:

Applications with detailed research curriculum vitae, a motivation letter and up to 3 reference letters should be sent by e-mail to Prof. Denis Kouamé and Prof Adrian Basarab.
Application deadline: opened until filled.
Starting date: as soon as possible.

References

[1] Gyongy, M. et al. (2009). Passive spatial mapping of inertial cavitation during HIFU exposure. IEEE Transactions on Biomedical Engineering, 57(1), 48-56.
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[3] Coviello, C. et al. (2015). Passive acoustic mapping utilizing optimal beamforming in ultrasound therapy monitoring. The Journal of the Acoustical Society of America, 137(5), 2573-2585.
[4] Boulos, P. et al. (2018). Weighting the passive acoustic mapping technique with the phase coherence factor for passive ultrasound imaging of ultrasound-induced cavitation. IEEE transactions on ultrasonics, ferroelectrics, and frequency control, 65(12), 23
[5] Polichetti, M. et al. (2021). Use of the Cross-Spectral Density Matrix for Enhanced Passive Ultrasound Imaging of Cavitation. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 68(4), 910-925.
[6] T Szasz, A Basarab, D Kouamé Beamforming through regularized inverse problems in ultrasound medical imaging IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Volume: 63, Issue: 12, December 2016
[7] Mohamad Hourani, Adrian Basarab, Denis Kouamé, Jean-Yves Tourneret, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, Volume: 68, Issue: 4, April 2021
[8] Sayantan Dutta, Adrian Basarab, Bertrand Georgeot, Denis KouaméDeep Unfolding of Image Denoising by Quantum Interactive Patches, 2022 IEEE International Conference on Image Processing (ICIP)