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Data Science for Quantitative Acoustic Microscopy (QAM)

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General context:

This 42-month postdoc, available from November 2022, is funded by a NIH grant gathering one research group in acoustic imaging from the Department of Radiology of Weill Cornell Medicine (New York City, PI Dr. Jonathan Mamou), one in statistical signal and image processing from Bristol University (PI. Prof. Alin Achim) and two in computational medical imaging from the University of Lyon (CREATIS lab, PI Prof. Adrian Basarab) and from the University of Toulouse (IRIT lab, Prof. Denis Kouamé). The postdoc will take place in Lyon, Campus de la Doua, in close collaboration with Prof. Denis Kouamé from the University of Toulouse (regular meeting, visits to Toulouse). Consortium meetings with the other members of the project will be organized every year, remotely and in person.

Applicative context:

QAM is a quantitative version of scanning acoustic microscopy (SAM). SAM forms fine-spatial resolution images of raster-scanned specimens using very-high-frequency ultrasonic excitations (i.e., > 100 MHz). SAM is well established in non-destructive testing and in studies of hard biological samples (e.g., bones). Over the last 30 years, SAM also has been used in soft-tissue studies that provide quantitative images of acoustic properties at frequencies typically near 100 MHz.
Signal processing algorithms developed previously by the consortium partners, simultaneously form 2D images of acoustic impedance, mass density, bulk modulus, speed of sound, compressibility, and acoustic attenuation, shown by our groups and others to bring new knowledge about diseases affecting bone, cartilage, brain, skin, heart, eye, liver and tumors.

Current challenges:

Our existing, fully operational laboratory QAM systems require expensive components (e.g., transducer, pulser, amplifier, digitizer, motor stages) and trained users. Scanning time can be long (e.g., ~ 5 min to scan an area of 1 mm by 1 mm); and experiments can be challenging because of the required precision in stage position. A small change in temperature (e.g., <0.5° C) of the drop of water used as coupling medium affects the QAM parameters and vibration amplitudes in the 100-nm range introduce errors. However, we already possess tools to address these and other challenges, and many of the challenges can be further mitigated by use of more expensive equipment (e.g., isolated and levitated tables, more-precise motor stages, and temperature-controlled scanning tanks).

Main objectives:

The innovation of the next generation of QAM instruments is that they can provide the best possible performance and robustness by employing advanced signal- and image-processing approaches never used to this extent in QAM to reduce or eliminate the need

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for such costly measures. Our new approaches will generate high-resolution images for a given QAM system while making it simpler, lower-cost, more-reliable, easier-to-use. Ultimately, our objective will be to make QAM technology easy to use as an optical microscopy system while providing quantitative information tissue information not available by any other microscopy modality.

Methodology:

The posdoc recruited will explore new computational imaging (inverse problems) algorithms to achieve the above-mentioned objectives. In particular, the postdoc will work on:
- fast acquisition techniques including compressed sensing able to decrease the acquisition time in QAM and reconstruct high quality-data from underspample measurements;
- resolution enhancement algorithms able to increase the spatial resolution of QAM maps;
- QAM parameter estimation from 3D RF data cubes.

Model-based (e.g., statistical) methods are powerful tools for solving image-reconstruction problems such as those addressed in QAM. Such inverse-model approaches require a forward model and an inversion process combining appropriate regularization and scalable optimization algorithms. However, tractable models may prove inaccurate in practical applications where the physics of data acquisition are complex and the images to reconstruct are difficult to approach by reliable statistical models. In stark contrast with analytical methods, data-driven machine learning (ML) methods do not make use of any kind of prior statistical information but instead make use of very large datasets to learn the solution to a given problem. Our vision is that when analytical methods based on statistical models are combined with data-driven approaches based on machine learning, very powerful computational QAM imaging algorithms can be conceived. The important quantity of QAM data already available at Weill Cornell Medicine is an important asset for training, validation and testing.

To resume, the aim of the postdoc is to develop innovative algorithms to reconstruct high-resolution QAM images from low-sampled data, using traditional inverse-problem based algorithms, physics-driven (supervised, weakly-supervised and non-supervised) learning approaches and hybrid unfolding deep learning networks.

Keywords:

Computational imaging, quantitative acoustic microscopy, inverse problems, compressed sensing, super-resolution, numerical optimization, deep learning, parameter estimation.

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.

Salary:

The salary will be determined by the administration based on the experience of the applicant (around 2,200 euros per month net), including health insurance and social coverage. The postdoc will participate to the scientific activities of the laboratory, in particular to seminars and working groups.

Application:

Applications with detailed research curriculum vitae, a motivation letter and up to 3 reference letters should be sent by e-mail to Prof Adrian Basarab and Prof. Denis Kouamé.

Application deadline: opened until filled.

Starting date: as soon as possible.