PhD Proposal 2019

School - Location: Aix-Marseille University, France

Laboratory: Laboratory of Mechanics and Acoustics (LMA), CNRS-AMU-ECM, Marseille, France http://www.lma.cnrs-mrs.fr

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Quantitative Ultrasonic Imaging in Diagnosis of Children Bone Diseases

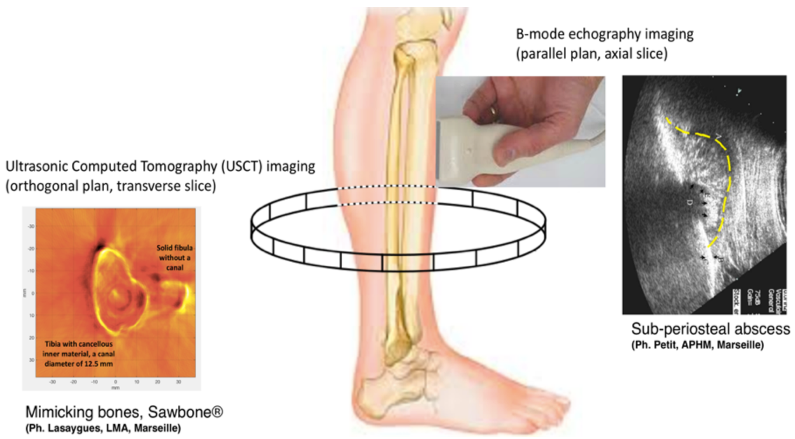
Scientific field: Biomedical Ultrasonic Imaging

Key words: Ultrasound imaging, tomography, inverse problems, bone tissue, pediatrics

Details for the subject:

Background, Context: For children's bone pathologies (tumors, non-union fractures, distraction), the development of ultrasonic imaging modalities is important challenges in order to provide an alternative to others imaging technics. Conventional modalities such as X-ray radiology or Computed Tomography (CT) which must be limited due to their radiation hazard. Magnetic Resonance Imaging is a major tool but require more frequently anesthesia [1] than CT and give poor cortical information. Nowadays, the B-mode ultrasound is the first-line examination for the diagnosis of many children's diseases. Due to its efficiency, the B-mode ultrasound is particularly dedicated to pediatric use, allowing to increase the number of procedures without harmful effects. However, B-mode ultrasound has difficulty penetrating bone and, therefore, can only see the outer surface of bony structures, and not what lies within them. A new and relevant research axis is then proposed in this PhD thesis: to develop an ultrasonic diagnostic modality for pediatric bone imaging with a parametric characterization of bone lesion.

Research subject: For several years, the Laboratory of Mechanics and Acoustics has been studying the diffraction-mode ultrasonic imaging of biological tissues. The developed methods are based on the ultrasonic computed tomography (USCT) principles provide images of soft medium. The acquisition geometry of the signals is no longer linear, as in B-mode ultrasound, but circular in the orthogonal plane, and based on a multi-channel and multi-frequency antenna. The main difficulty of the USCT applied in the case of bone



imaging is the large impedance contrast between echogenic structures and the surrounding soft tissues. In that context, approximation methods commonly for soft tissues fail to provide quantitative images. We have then suggested a purely numerical non-linear inversion algorithm, and the minimization procedure between the full recorded and simulated data is solved. The main objective of the PhD thesis is to develop a real prototype of predictive analysis and diagnosis of the pediatric skeleton based on USCT. The locks associated with an in vivo configuration are still numerous: the number of transducers, the power and the intensity of the wave, the image resolution and the contrast in the deep zone, the accessibility of non-peripheral skeletal sites, or in between the two leg and arm bones, and the muscle and soft tissue effect in term of dispersion and attenuation of the wave.

Work plan: Tasks are based on combining numerical and experimental benchmark tests in order to optimize the signal processing and to gradually integrate a realistic clinical model.

(*Task no1*) The simulation of ultrasonic waves propagation is an efficient way to gain insight into bone imaging, to optimize the device configuration (number of sensors, the generated wave field), and to integrate all the complexity of the in vivo configuration (skin, muscle, paired bone). A numerical technique well adapted to handle such problems is the finite-difference method. Indeed, the position of the interfaces between the bone and the surrounding environment is a priori unknown, and the spatial discretization of the problem is therefore based on a regular grid, for which finite differences are well suited. Moreover, this formulation works fine for both solid, fluid, and fluid/solid media in contact we propose to handle the problem in 2D using a tool developed by LMA's team [2].

(*Task no2*) The proposed (diffraction-mode) acoustical imaging method introduced will use the so-called full waveform inversion (FWI) algorithm, based on a full numerical modeling of wave propagation in the medium. The term "full" refers to the use of the full-time series. The aim is to simultaneously reconstruct the compression and shear waves in the bone, and without considering that the tissue density is spatially constant as in previous methods. The ambitious goal is to make children's bone imaging become morphological and parametric [3].

(*Task no3*) Tests with calibrated and academic bone mimicking phantoms as well as real animal and human bones will be done. To enhance the Contrast-to-Noise Ratio, a wavelet processing method will investigate [4]. Comparative tests will be carried out in the Department of Pediatric and Prenatal Radiology at Timone Children’s Hospital in Marseille (APHM).

References:

[1] P. Petit *et al.*, “Rate of Abnormal Osteoarticular Radiographic Findings in Pediatric Patients,” *Am. J. Roentgenol.*, vol. 176, no. 4, pp. 987–990, Apr. 2001.

[2] V. Monteiller, S. Chevrot, D. Komatitsch, and Y. Wang, “Three-dimensional full waveform inversion of short-period teleseismic wavefields based upon the SEM-DSM hybrid method,” *Geophys. J. Int.*, vol. 202, no. 2, pp. 811–827, May 2015.

[3] S. Bernard, V. Monteiller, D. Komatitsch, and P. Lasaygues, “Ultrasonic computed tomography based on full-waveform inversion for bone quantitative imaging,” *Phys. Med. Biol.*, vol. 62, no. 17, pp. 7011–7035, Aug. 2017.

[4] P. Lasaygues *et al.*, “Contrast resolution enhancement of Ultrasonic Computed Tomography using a wavelet-based method – Preliminary results in bone imaging,” in *Proceedings of the Int. Workshop on Medical Ultrasound Tomography*, Speyer, Germany, 2017, pp. 291–302.

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