CREATIS

UNIVERSITÉ DE LYON

Master's Internship 2024

Subject: Magnetic Resonance Elastography: Non Linear Inversion for the reconstruction of viscoelastic parameters

Duration: 6 months

Location: MAGICS team of CREATIS laboratory. Bâtiment Léonard de Vinci Campus La Doua, 21 avenue Jean Capelle, 69621 Villeurbanne, France

Description and aim of the internship:

This project falls within the field of medical imaging, with its application area being Magnetic Resonance Elastography (MRE). This imaging technique allows for mapping the biomechanical properties of soft tissues such as the brain or liver using images acquired through Magnetic Resonance Imaging (MRI)[1]. There is currently no imaging method capable of directly mapping biomechanical properties, such as elasticity and viscosity. Thus, MRE involves three steps. First, using an external actuator such as a pneumatic or piezoelectric system, the tissue of interest is mechanically stimulated, inducing the propagation of a shear wave within the tissue. The generated displacements are then measured using a specific MRI sequence, yielding a series of volumetric images depicting wave motion in three orthogonal spatial directions. Finally, these wave images are processed using a dedicated numerical reconstruction algorithm which enables the identification of the biomechanical properties of the tissue under investigation, based on its response to a controlled stimulation. The commonly used algorithm is based on the inversion of the wave equation[2]. More complex algorithms, such as the Nonlinear Inversion (NLI)[3] method, are currently being explored. NLI is based on meshing the tissue and defining the mechanical properties at each node of the mesh. Solving the inverse problem involves finding the mechanical parameters of the mesh that allow simulating the propagation of a wave minimizing the differences with the acquired wave images. NLI could thus offer a better characterization of biomechanical parameters from multi-frequency MRE[4] data, considering factors like tissue behavior laws and tissue anisotropy. An overview of MRE and NLI reconstruction method is provided in Figure 1.

The proposed research project specifically aims to study the performance of the NLI reconstruction algorithm compared to the algorithm traditionally used. Images will be acquired on a preclinical MRI where various parameters such as field of view, image resolution, and wave frequencies are significantly different from those encountered in clinical settings, where the NLI method has been developed and tested. Multi-frequency MRE data will be acquired using a preclinical MRI on the PILoT imaging platform, using samples created to simulate various *in vivo* scenarios. This internship will be jointly supervised by E. Van-Houten from the University of Sherbrooke (video conference meetings are planned) and may benefit from the use of the 'Calcul Canada' infrastructure for performing numerical computations.

More specifically, the objectives of the internship will be as follows:

- Optimize the parameter settings for the reconstruction of biomechanical properties using the NLI method: subzone size, mesh resolution, boundary conditions, etc.
- Reconstruct a series of multi-frequency MRE data using the NLI method, acquired at 7T on plastisol and agarose phantoms with inclusions of different sizes and stiffnesses.
- Verify and compare the viscoelastic behavior of agarose and plastisol according to rheological laws.

- Compare the results obtained by NLI with the conventional reconstruction based on the wave equation inversion and draw conclusions about the potential of the NLI method on preclinical MRE data.

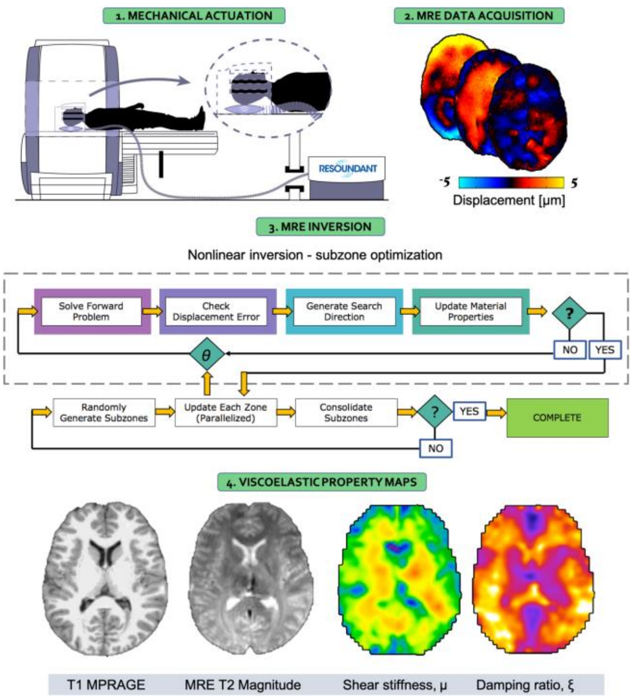

Figure 1. Overview of the MRE imaging and analysis procedure. In the first step, shear waves at 50 Hz are introduced in the brain via a pneumatic actuation system. The resulting tissue deformation is captured using an MRE sequence and displacement data is captured along three orthogonal axes (anterior–posterior, right–left, and superior–inferior). The displacement data along with a binary brain mask is supplied to the nonlinear algorithm, which models tissue as a heterogenous, viscoelastic material. A subzone optimization procedure is used to iteratively update the property description in a finite element computational model to minimize the difference between the model displacements and the measured displacement data. Finally, maps of the complex shear modulus are converted to shear stiffness, $\mu=2|G^*|2/(G+|G^*|)$*, and damping ratio,* $\xi=G''/2G'$*. The subject specific T1-weighted MPRAGE and MRE T2 magnitude images are provided to illustrate the images required for the spatial normalization procedure.*

Figure from Hiscox et al., Hum Brain Mapp, 2020

Candidate profile:

Skills in biomechanics and MATLAB programming for data processing are required. Knowledge in MRI physics would be appreciated and an affinity for experimental measurements is desirable.

References:

1. Asbach P, Klatt D, Hamhaber U, et al. Assessment of liver viscoelasticity using multifrequency MR elastography. Magnetic Resonance in Medicine. 2008;60(2):373-379.
2. Oliphant TE, Manduca A, Ehman RL, Greenleaf JF. Complex-valued stiffness reconstruction for magnetic resonance elastography by algebraic inversion of the differential equation. Magnetic Resonance in Medicine. 2001;45(2):299-310.
3. Three-dimensional subzone-based reconstruction algorithm for MR elastography, EEW Van Houten *et al.*, Magnetic Resonance in Medicine, 45(5), pp. 827—837, 2001.
4. Viscoelastic power law parameters of in vivo human brain estimated by MR elastography, J Testu *et al.*, Journal of the mechanical behavior of biomedical materials, 74, pp. 333—341, 2017.

Supervision:

Pilar SANGO-SOLANAS and Kevin TSE VE KOON : CREATIS

Elijah VAN HOUTEN : Université de Sherbrooke

Application:

Send a CV and a cover letter to Pilar.Sango@creatis.univ-lyon1.fr and kevin.tsevekoon@creatis.univ-lyon1.fr