Internship proposition

Academic Year: ……2025/2026…

Project title: Development of an identification framework for hyper- and visco-elastic constitutive laws for soft biological tissues

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Project description

Soft biological tissues are involved in many biomedical applications, from cardiovascular to digestive, from movement to neurology. Understanding their behavior can help analyzing their state (healthy or pathological), computing their response to a specific gesture, or predicting their interaction with medical devices. Soft tissues exhibit non-linear viscoelasticity, coupled with porous phenomena and potential damage.

To characterize them, several methods are deployed, in-vivo and in-vitro, from ultrasound elastography to mechanical testing, associated to various ways to measure their response. However there remain several open questions on the identification of their behavior, related to experimental protocols and modeling assumptions. It is still difficult to choose the appropriate constitutive law and generate the relevant experimental data to ensure the robust identification of all the parameters of this law. It was notably shown in C4Bio European project, in which LBMC is involved, that it is very difficult to reproduce both experimental conditions and identified parameters. Researchers explore various ways to improve the identifiability of model, e.g. using multimodal measurements [1] or exploring innovative experimental designs to acquire rich enough data [2] Lately, the paradigm changed towards neural-network based identification, called model discovery [3].

This project aims to develop a framework to link classical hyperelastic and viscoelastic laws to the required experimental data to promote the parameters identifiability, notably using full-field measurements. We aim to explore isotropic and anisotropic constitutive laws, along with viscoelasticity, for both membranous and 3D tissues.

The first step will be to develop a generic inverse identification method adaptable to different cost functions and measured quantities (forces, displacement, displacement fields, pressure, etc). The second step will be to test the identification process based on synthetic data generated by Finite Element simulation, for various types of tests and constitutive laws. The third step will be to evaluate the mechanical response sensitivity to the model parameters, to evaluate their identifiability and generate experimental good practice. A special focus will be on the effect of pretension all across the identification process.

This project is strategic for LBMC, which is expert in soft tissue experimentation and can develop advanced experimental methods to feed models, driven by the knowledge acquired during this project.

[1] N. Fougeron, Z. Oddes, A. Ashkenazi, et D. Solav, « Identification of constitutive materials of bi-layer soft tissues from multimodal indentations », *J. Mech. Behav. Biomed. Mater.*, vol. 155, p. 106572, 2024.
[2] A. Asadi et K. Laksari, « Optimal Experimental Design for Repeatable Hyperelastic Material Characterization », *J. Mech. Behav. Biomed. Mater.*, p. 107104, juin 2025, doi: 10.1016/j.jmbbm.2025.107104.
[3] M. Peirlinck, K. Linka, J. A. Hurtado, G. A. Holzapfel, et E. Kuhl, « Democratizing biomedical simulation through automated model discovery and a universal material subroutine », *Comput. Mech.*, vol. 75, n° 6, p. 1703-1723, juin 2025, doi: 10.1007/s00466-024-02515-y.