M2 Internship – Spring 2027 – 5 to 6 months

Development of an identification framework for anisotropic hyperelastic tissues in multiaxial loading – Application to soft connective tissues

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. In a previous internship, a Python application was developed to import experimental data, identify isotropic and anisotropic hyperelastic laws and evaluate the material parameters identifiability from uniaxial tests.

The internship objective will be to extend this application to other loading conditions, in particular biaxial tension and pure shear, and richer constitutive laws, to reproduce the behaviour of soft connective membranes. It will involve both analytical development and numerical implementation in the framework of hyperelasticity, and experimental campaigns on synthetic and biological tissues – in particular the fascia - to evaluate the application performances on real-life cases.

Skills required: The candidate should have a background in continuum mechanics. Python coding and non-linear mechanics skills would be appreciated.

Laboratory: Laboratoire de Biomécanique des Chocs – LBMC UMR_T9406 – https://lbmc.univ-gustave-eiffel.fr/

Location: Université Gustave Eiffel, **Campus de Lyon**, 25 Avenue François Mitterrand, 69675 BRON Cedex FRANCE

Supervisors to contact: Aline Bel-Brunon, Research director (aline.bel-brunon@univ-eiffel.fr) and Mélanie Ottenio, Assistant Professor (melanie.ottenio@univ-lyon1.fr)

How to apply: send your academic transcript, cover letter and CV to the two supervisors.

[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, nº 6, p. 1703-1723, juin 2025, doi: 10.1007/s00466-024-02515-y.