Call for a 18-month post-doctoral fellowship

High-performance computing and domain decomposition methods: applications to numerical simulations in biomechanics

Keywords

HPC techniques; Computational mechanics; Open MP–MPI; Domain decomposition methods; High-Performance Computing; Non-linear elasticity; Frictional contact; Plasticity; Biomechanics; Large strains.

Supervisors

- Francesco Bonaldi (`francesco.bonaldi@univ-perp.fr`), Principal Investigator;
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- Serge Dumont (`serge.dumont@univ-perp.fr`).

In the framework of French Research Agency grant **MaNStarT** ("Mathematical, mechanical, and Numerical modeling of Stents in arterial Tissues"), funding is available at LAMPS (*Laboratoire de Modélisation Pluridisciplinaire et Simulations*), University of Perpignan (France), for a **one-year-and-a-half** postdoc position. Further collaborations are expected with the University of Montpellier, at the *Laboratoire de Mécanique et Génie Civil* (LMGC), as well as with ***Sim&Cure***, based in Montpellier. Starting date is **flexible**, between Spring/Summer 2025 and Autumn 2026.

Context

Numerical simulation of some problems arising in biomechanics, such as the deployment of stents by contact in soft biological tissues, is particularly costly in terms of computing resources. On the one hand, this is due to the geometry of the domains involved, which is sometimes characterized by very fine details, which gives rise to large-size problems; on the other hand, the mathematical modeling of the mechanical problem involves nonlinearities at several levels, coming from the laws that describe the behavior of the materials that constitute the bodies, as well as phenomena such as contact, friction, adhesion, etc.

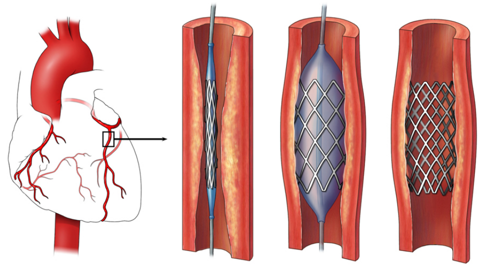

Figure 1: Stent in an arterial tissue, deployed by inflation with a balloon.

Research program

The objective of this project is to design and implement domain decomposition methods for solving problems from biomechanics (and of interest for biomedicine), in such a way as to be able to exploit

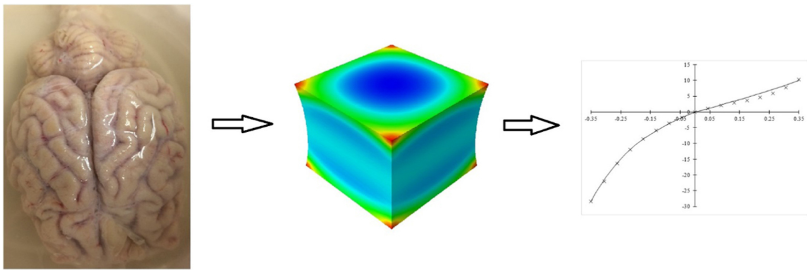

Figure 2: Non-linear stress-strain relation for soft biological tissues.

parallel computing techniques (HPC, High-Performance Computing) on machines with an adapted architecture. Given the complexity of the models involved, and in order to obtain results in three dimensions of space, high-performance computing techniques will play a central role for the numerical simulation of such problems.

Computations will be performed on the HPC@LR MUSE server, based in Montpellier. To improve the computational efficiency, we will implement domain decomposition algorithms. This domain decomposition strategy will be based on the combination of a generalized Newton method, to overcome the difficulty of non-linearity, and a Schur complement method with the use of additive Schwarz subspaces, allowing to solve the non-symmetric linearized interface problem. More specifically, the choice of the coarse space will be correctly adapted to the mathematical model of the problem (dynamic and non-symmetric) in order to obtain the numerical scalability of the solver. The implementation will be carried out in parallel, which will allow to demonstrate the potential efficiency of the method. The validation step of the developed numerical methods (comparison of numerical results with those provided by mechanical test experiments) will be carried out in collaboration with the Laboratory of Mechanics and Civil Engineering (LMGC) of the University of Montpellier, and in particular with Professor Franck Jourdan, as well as with the company ***Sim&Cure***, represented in particular by Christophe Chnafa (Strategy Officer) and Sophie Bruge (R&D Director), also located in Montpellier.

Requirements

Candidates should possess an excellent knowledge in the fields of parallel computing techniques, in particular Open MP and MPI, as well as domain decomposition methods. Ideally, they should be also interested in applications in continuum mechanics.

How to apply

Send an email to `francesco.bonaldi@univ-perp.fr` and to `barboteu@univ-perp.fr` with a detailed curriculum vitæ including a list of reference persons, and possibly a motivation letter.