PostDoc - GPU-Accelerated Mesh Generation for Patient-Specific Stent Simulation

Advanced Anisotropic Meshing for Cerebrovascular Digital Twins

Context

Endovascular stenting is a major treatment strategy for intracranial aneurysms. However, evaluating the hemodynamic impact of a stent before treatment remains a major challenge. Reliable simulation requires accurate representation of the stent wire structure embedded in the arterial geometry, which introduces extremely complex geometric features and multiple spatial scales.

The ability to generate high-quality computational meshes for such geometries is therefore a key technological bottleneck. Successfully addressing this challenge would enable fast and reliable patient-specific simulations of stent deployment and post-treatment hemodynamics, opening the way toward clinical decision-support tools.

This postdoctoral project is part of the ERC CURE project, which aims to develop fast patient-specific computational models to assist the treatment of cerebral aneurysms. A central component of this effort is the development of robust and efficient meshing technologies capable of handling highly complex vascular geometries and embedded medical devices.

In a context where computational pipelines are expected to deliver results within minutes rather than hours, revisiting and accelerating our meshing technology represents a major step toward real-time or near-real-time hemodynamic simulation.

Objectives

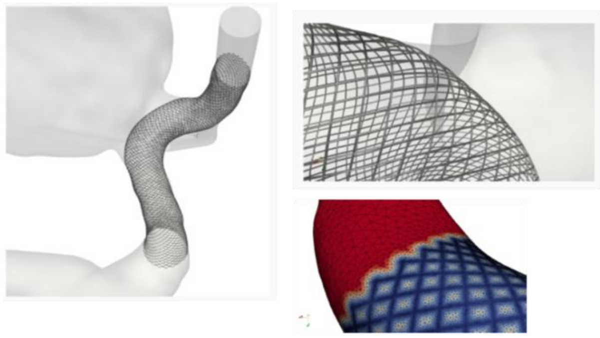
The objective of this project is to redesign and accelerate the MTC meshing framework, a widely used simplex-based mesh generator, by enabling GPU-based execution and hybrid CPU–GPU workflows. The research will focus on three main aspects.

1. GPU Acceleration of the MTC Mesh Generator

MTC is a simplex-based mesh generator and remesher (triangles, tetrahedra, and higher-dimensional simplices) widely used in mesh generation, mesh adaptation, and anisotropic remeshing procedures in both academic libraries and industrial simulation codes. The first objective of the project is to develop a GPU-capable version of the MTC mesher, allowing the exploitation of modern general-purpose graphics processors (GPGPU). This will require redesigning core algorithms to leverage massively parallel architectures while preserving the mathematical robustness of the original meshing framework. The implementation may rely on technologies such as CUDA, OpenCL, or hybrid CPU–GPU approaches, with the goal of significantly accelerating mesh generation and remeshing operations.

2. Anisotropic Mesh Adaptation and Parallel Mesh Operations

MTC can be coupled with metric fields to generate highly anisotropic meshes adapted to physical solution features. These metric fields may be defined analytically or derived from a posteriori error estimate. The project will explore GPU-enabled implementations of anisotropic mesh adaptation techniques, including dynamic remeshing and field interpolation within the CimLib_CFD parallel computing framework, which provides dynamic mesh partitioning and transparent data redistribution for large-scale simulations. This will enable efficient mesh adaptation workflows compatible with high-performance computing and large-scale simulations.



3. Application to Patient-Specific Stent Modeling

The final objective of the project is the application of these technologies to the simulation of intracranial aneurysm treatment, within the ERC CURE framework. Patient-specific vascular geometries combined with detailed stent wire structures lead to extremely challenging meshing problems due to: large differences in spatial scales, highly complex braided wire geometries and tight geometric constraints near the arterial wall.

The development of robust GPU-accelerated meshing algorithms capable of generating such meshes will enable fast and reliable CFD simulations of stented arteries, a critical step toward predictive evaluation of treatment outcomes.

Scientific Environment

The postdoctoral position will take place at CEMEF (Centre de Mise en Forme des Matériaux), a joint research center of MINES Paris – PSL and CNRS, located in Sophia-Antipolis, France, equipped with a 3000 cores CPU cluster, A100 and H100 GPUs. The successful candidate will join the Computing and Fluids (CFL) group, an internationally recognized team working on computational fluid dynamics, mesh generation and adaptation, high-performance computing, scientific machine learning The group develops large-scale numerical tools and collaborates closely with both academic and clinical partners within the ERC CURE project. The project will benefit from access to high-performance computing platforms and GPU clusters.

Keywords

Mesh generation; Anisotropic mesh adaptation; GPU computing; High-performance computing; Computational geometry; CFD; Medical simulation; Cerebral aneurysms; Stent modeling

Duration

12 to 18 months

Candidate Profile and Skills

PhD in applied mathematics, computer science, computational mechanics, or scientific computing. Strong programming skills are required, particularly in: C or C++, GPU programming (CUDA and/or OpenCL), computational geometry, mesh generation and adaptation, parallel computing, numerical simulation. The candidate should demonstrate strong interest in high-performance scientific computing and algorithm development.

About MINES Paris – PSL / CEMEF

CEMEF is a leading research institute in France, conducting research at the intersection of materials science, mechanics, data science, and industrial transformation processes. The successful candidate will join the Computing and Fluids (CFL) group, an internationally recognized team working on advanced numerical simulation, high-performance computing, and scientific machine learning applied to complex industrial and physical systems. CFL was awarded by Atos Joseph Fourier Award as one of the best national research group in High Performance Computing.

Contacts

Elie Hachem : elie.hachem@minesparis.psl.eu
Thierry Coupez : thierry.coupez@minesparis.psl.eu