INTERNSHIP OFFER
IsoGeometric Analysis (IGA) implementation in the open-source software SOFA (M/W)

The University of Luxembourg was founded in 2003, right at the heart of the European Union. Strongly focused on research, it aspires to be one of Europe's most highly regarded universities with a distinctly international, multilingual, and interdisciplinary character. Teaching, research, and knowledge transfer at the highest international level are three goals we set ourselves. The Legato team led by Professor Stéphane Bordas aims to build intuitive and interactive platforms for computational mechanics problems that allow the users to interact with their models and hence gain insights into peculiar and counter-intuitive phenomena.

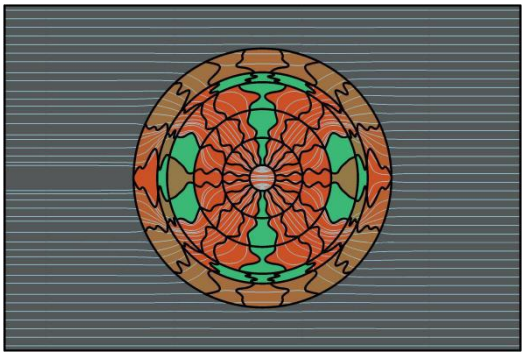

Figure 1: Heat manipulator simulation using IsoGeometric Analysis (IGA).

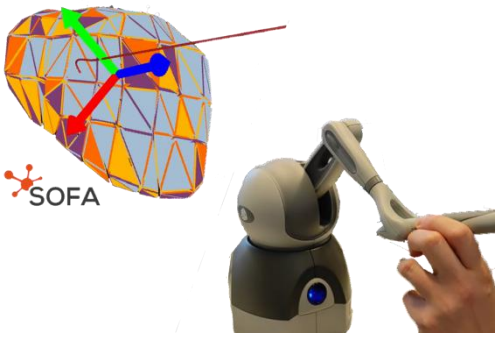

Figure 2: Liver surgery controlled by haptic robot.

General context

SOFA (Simulation Open Framework Architecture) was created in 2007 by a joint effort from INRIA, CNRS, USTL, UJF, and MGH. Such software aims to provide an efficient framework dedicated to research, prototyping, and the development of physics-based simulations. It is an open-source library distributed under the LGPL2 license, hosted on GitHub, and developed by an international community. SOFA is modular. Indeed, it is made of a core application orchestrated by a consortium. Meanwhile, users can create public or private plugins to offer additional features that can be activated to the users' needs.

INTERNSHIP OFFER
IsoGeometric Analysis (IGA) implementation in the open-source software SOFA (M/W)

SOFA is an efficient C++ library, including Python wrappers for a user-friendly prototyping interface. It was originally designed for deformable solid mechanics but has been applied in various domains such as robotics, registration, fluid simulations, model-order reduction, or haptic simulations. SOFA exhibits many attractive features, but among them, multi-model representation and mappings differentiate it from other software.

Specific context

In order to simulate the mechanical deformation of an object, numerical models such as FEA (Finite Element Analysis) are classically used. Conventional FEA utilizes the Lagrange shape functions. On the other hand, Computer-Aided Design (CAD) packages create Non-Uniform Rational B-splines (NURBS)-based geometries. Because of this difference in geometrical representations, the CAD geometries need to be approximated and made analysis suitable before using in FEA. The approximation, however, becomes one of the main bottlenecks of the design process by taking a considerable amount of computational time. To circumvent this problem, TJR Hughes et al. (2005) proposed the IsoGeometric Analysis (IGA), an approach based on the conventional FEA which utilizes NURBS shape functions instead of Lagrange shape functions. The IGA allows seamless coordination between CAD modelling and analysis. The University of Luxembourg has already applied IGA for the optimization problems of the heat manipulators. The internship goal is to translate the MATLAB script into the complex C++ architecture of SOFA to allow real-time simulations directly from the CAD files.

INTERNSHIP OFFER
IsoGeometric Analysis (IGA) implementation in the open-source software SOFA (M/W)

Tasks to complete

The main undertakings are the following :

- Getting in touch with the MATLAB and C++ code and understanding the basics of IGA and FEM.
- Transcribing the MATLAB code into C++ code.
- Running basic mechanical tests to ensure soundness and correlation of the results with analytical solutions and move to more complex scenarios.
- Implementing unittests, CI/CD pipelines, dockerization and ensuring compatibility with the main branch of the SOFA consortium.
- If the time allows, move to thermal flux simulations.

Competences

Applied mathematics, numerical methods, FEM, informatics programming, mechanics.

Profile

- Post-graduate student.
- Education in applied mathematics, mechanical engineering, or informatics.
- Solid basis in informatics programming (MATLAB, C++, and Python are required).
- Some knowledge about pybind, unittests, Github actions and Git is highly appreciated.

INTERNSHIP OFFER
IsoGeometric Analysis (IGA) implementation in the open-source software SOFA (M/W)

- Some basic knowledge on FEM and IGA is appreciated.

Conditions

- Duration : 4 to 6 months starting August/September 2022
- Wage : Competitive salary
- Place : University of Luxembourg, Belval campus in Computational Science department (Maison du Nombre)
- Contacts : Professor Stéphane Bordas: stephane.bordas@uni.lu, Arnaud Mazier: arnaud.mazier@uni.lu, and Chintankumar Jansari: chintankumar.jansari@uni.lu

Bibliography

- Faure, F., Duriez, C., Delingette, H., Allard, J., Gilles, B., Marchesseau, S., Cotin, S. (2012). *SOFA: A Multi-Model Framework for Interactive Physical Simulation*. 283–321. https://doi.org/10.1007/8415_2012_125
- Hughes, T. J. R., Cottrell, J. A., & Bazilevs, Y. (2005). Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement. *Computer Methods in Applied Mechanics and Engineering*. https://doi.org/10.1016/j.cma.2004.10.008
- Jansari, C., Bordas, S., & Atroshchenko, E. (2022). Design of metamaterial-based heat manipulators by isogeometric shape optimization. *International Journal of Heat and Mass Transfer (Accepted) arXiv:2205.08775*.