PhD thesis - Year 2018

Isogeometric Discontinuous Galerkin method with moving interfaces

Inria Sophia Antipolis - Méditerranée Research Center
Acumes Project-Team
2004 Route des Lucioles, BP 92, 06902 Sophia Antipolis Cedex, France

Context

Acumes Project-Team (http://team.inria.fr/acumes) is a joined team from Inria Sophia Antipolis - Méditerranée Research Center and mathematics laboratory Jean-Alexandre Dieudonné at University of Nice. The research conducted concerns the analysis and optimization of systems governed by partial differential equations, with applications ranging from fluid and structural mechanics to modeling of biological phenomena, road and pedestrian traffic. in this context, the development of efficient numerical schemes plays a major role in the team.

For some years, a new simulation paradigm has been emerging, the *isogeometric analysis*, which consists in solving partial differential equations by a variational approach, using NURBS (Non-Uniform Rational B-Spline) bases originating from CAD (Computer-Aided Design) domain. This approach has the advantage to allow a resolution without geometrical approximation, i.e. with a computational domain supported *exactly* by the CAD geometry, contrary to classical mesh-based methods that approximate the geometry by local linearization. Consequently, isogeometric analysis relies on a unique high-order representation for both the geometry and the fields to solve, yielding a significant gain in terms of accuracy and ease of interaction. This approach has been popularized by T. Hughes [CHB09], mainly for elliptic and parabolic problems.

Acumes Project-Team has recently proposed a formulation dedicated to hyperbolic problems, based on a Discontinuous Galerkin method [Duv18]. This approach has been applied to compressible aerodynamics in the context of Euler, and then Navier-Stokes, equations including strategies for local refinement and shock capturing.

Objective

The aim of this work is to study the extension of the proposed isogeometric Discontinuous Galerkin method to problems with moving interfaces, for which the computational domain is subject to displacements. Different problems are targeted, such as sensitivity analysis with shape parameters, for which the solution changes due to local geometrical perturbations are estimated, or problems involving deformable or moving (translated, rotated) bodies, for which the global displacement is explicitly imposed. One can also study problems with fluid-structure interactions, for which the displacement is ruled by a physical coupling. The accuracy of the proposed approach will by especially investigated, including comparison with classical mesh-based methods. The gain of using a high-order and geometrically exact computational domain will be quantified.

Work to achieve

The doctoral student will be part of the Acumes Project-Team at Inria Sophia Antipolis - Méditerranée Research Center. At first, he/she will have to formalize the targeted extensions in the context of the isogeometric Discontinuous Galerkin method. Regarding sensitivity analysis, the development will rely on the continuous sensitivity equation method, which consists in solving additional partial differential equations obtained by differentiating the state equations with respect to the geometry [DP06]. This approach is *a priori* well adapted to high-order NURBS representations. Regarding analysis with moving computational domains, the work will rely on the ALE (Arbitrary Lagrangian-Eulerian) [PPB09] formulation, which has to be extended to high-order NURBS descriptions.

On the basis of the existing code (C++ language) solving Euler/Navier-Stokes equations on NURBS domains, the doctoral student will implement the proposed approaches and will conduct a set of numerical tests based on academic and then industrial problems, in order to qualify the methods and quantify their accuracy. The targeted applications concern compressible flows around airfoils or tubine blades.

Profile

The candidate must hold a Master's degree (or equivalent) in scientific computing / applied mathematics. Knowledge in C ++ is required. An experience in numerical simulation, high-performance computing, high-order schemes is a plus.

Director: Regis Duvigneau

Contact: regis.duvigneau@inria.fr

Link: `http://team.inria.fr/acumes`

Duration: 3 years

Location: Inria Sophia Antipolis - Méditerranée Research Center

Salary: around 2000€(without tax)

References

[CHB09] J.A. Cottrell, T.J.R. Hughes, and Y. Bazilevs. *Isogeometric analysis : towards integration of CAD and FEA*. John Wiley & sons, 2009.

[DP06] R. Duvigneau and D. Pelletier. On accurate boundary conditions for a shape sensitivity equation method. *Int. J. for Numerical Methods in Fluids*, 50(2), 2006.

[Duv18] R. Duvigneau. Isogeometric analysis for compressible flows using a Discontinuous Galerkin method. *Computer Methods in Applied Mechanics and Engineering*, 2018.

[PPB09] P.-O. Persson, J. Peraire, and J. Bonet. Discontinuous Galerkin solution of the Navier–Stokes equations on deformable domains. *Computer Methods in Applied Mechanics and Engineering*, 198(17-20):1585–1595, 2009.