PROPOSITION DE SUJET DE THESE

Intitulé : Nonlinear model reduction strategies for advection-dominated flows within a high-order Discontinuous Galerkin framework: application to turbo-machinery.

Référence : **SNA-DAAA-2022-19**
(à rappeler dans toute correspondance)

Début de la thèse : 1/10/2022	**Date limite de candidature :** 20/5/2022

Mots clés

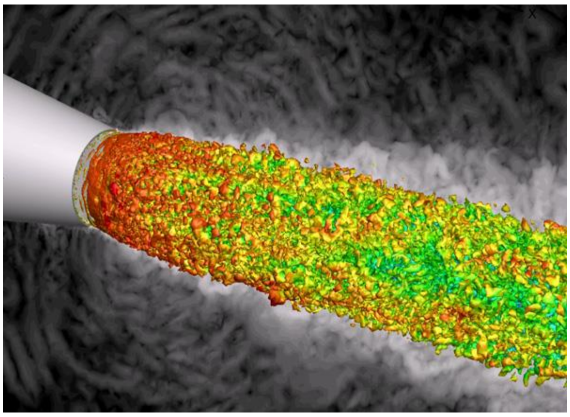
MOR, Parametrized Problems, Discontinuous Galerkin Method, High Order Numerical Methods, turbo-machinery.

Profil et compétences recherchées

The ideal candidate should have experience in numerical methods for PDEs, and he/she should have good programming skills in OOP (Python and/or C/C++ appreciated) and Fortran 90/95. The candidate should also be familiar with the domain of CFD. Familiarity with machine learning and/or optimization methods is also highly appreciated.

Présentation du projet doctoral, contexte et objectif

A wealth of applications in science and engineering — such as optimal control, real-time computing, and design optimization — involves the solution of computational fluid dynamics (CFD) problems for many different system configurations. For this class of problems, due to the huge number of points involved in the computation, it is important to reduce the marginal (i.e., in the limit of many queries) cost associated with a given simulation over a range of parameters [2]. Model order reduction (MOR) techniques rely on an offline/online decomposition to reduce marginal costs.



Turbulent jet computation with Aghora (M. Lorteau, ONERA)

- During the offline or learning phase, we rely on high-fidelity (hf) simulations to generate a reduced-order model (ROM) to estimate the solution over a range of parameters. In the background, at ONERA, we are developing high-order Discontinuous Galerkin (DG) flow solvers which enable a high precision on unstructured grids and that allow to obtain an accurate representation of flows around obstacles with complex geometries. Namely, the code Aghora, enables DG schemes for high-speed and compressible turbulent flows, featuring various modeling approaches such as RANS LES, mesh and polynomial degree adaptation based on ad-hoc spectral error estimators. The goal of the present project is to develop model order reduction techniques within the high-order DG solver ans hence inside the Aghora code.
- During the online or prediction phase, given a new value of the parameter, we query the ROM to estimate the solution field and relevant quantities of interest.

MOR shares the same objective with supervised learning (SL) in machine learning: SL is the task of learning a function that maps an input to an output based on example input-output pairs; in MOR the input is the parameter and the output corresponds to the hf state. We note, however, two key differences between the two frameworks: first, in MOR a parametric physics-based model is available at prediction stage; second, in MOR the dataset of input-output pairs is not provided a priori, but might be chosen progressively at training stage. The former motivates the interest in MOR for projection-based methods that rely on the projection of the equations onto a suitable low-dimensional space to devise a physics-based ROM for online predictions; The vast majority of MOR methods relies on the approximation of the solution field as the linear combination of empirical modes.
Despite their success for a broad class of problems, the inadequacy of linear approximations to deal with parametric fields with displacing coherent (essentially compact support) structures fundamentally hinders the application of linear model reduction to advection-dominated problems with shocks or wakes [5]. Fluid mechanics practical problems we need to address are full of this kind of structures. One example is the transonic flight, common condition for commercial aircraft. This motivates the interest towards nonlinear approximations, which involve a nonlinear relationship between the latent coefficients of the projection and the approximated solution.

In this project, we consider the development of registration techniques to generate mappings for MOR [2]. In computer vision and pattern recognition, registration refers to the process of finding a spatial transformation that aligns two datasets; in the framework of model reduction, registration aims to find a parametric transformation (i.e., a bijective mapping) to track moving features such as shocks and contact discontinuities, and ultimately improve performance of linear compression methods (e.g., proper orthogonal decomposition).

The final objective of the PhD is the application of the methodology developed to the NASA Rotor 37 test case [6], a complex parametric test case for turbo-machinery applications.

Bibliography :

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Collaborations envisagées	
INRIA Bordeaux (équipe MEMFIS), chaire PROVE	
Laboratoire d'accueil à l'ONERA Département : Département d'Aérodynamique Aéroélasticité Acoustique (DAAA) Lieu (centre ONERA) : Châtillon **Contact** : A. Remigi, J.-B. Chapelier, S. Beneddine Email : alberto.remigi@onera.fr	**Directeur de thèse** Nom : A. Iollo, Laboratoire : Institut de Mathématique de Bordeaux (équipe MEMFIS) Tél. : Email :angelo.iollo@math.u-bordeaux.fr

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