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PROPOSITION DE SUJET DE THÈSE

Intitulé : Design of high-order filters for Large-Eddy Simulation using Discontinuous Galerkin schemes on unstructured grids

Référence : SNA-DAAA-2023-004
(à rappeler dans toute correspondance)

Début de thèse envisagé : september/october 2023

Date limite de candidature : May 2023

Mots clés

Discontinuous Galerkin, high order filters, unstructured meshes, Large-Eddy Simulation

Profil et compétences recherchées : Grandes écoles/master 2 recherche, numerical analysis, scientific computing, programming (object oriented C++, python), knowledge in fluid dynamics and turbulence

Présentation du projet doctoral, contexte et objectif

The Discontinuous Galerkin (DG) numerical schemes provide a strong interest for the accurate simulation of turbulent flows over complex geometries, as they combine an arbitrary high-order of accuracy with an ability to handle complex, unstructured meshes. In this context, this class of methods is often employed for performing Large-Eddy Simulation (LES), a technique which aims at representing explicitly the spatial and temporal development of the largest vortices of the flow configuration while modeling the subgrid or subfilter scales. However, DG simulations performed on coarse meshes can display unphysical numerical artefacts as the continuity of the solution across mesh elements is not enforced [1]. In this context, we seek at developing an explicitly filtered LES methodology fit for DG schemes, which also allows for controlling the numerical error of the scheme which can interact with the LES model terms [2]. In particular, Smoothness Increasing Accuracy Preserving (SIAC) filters seem to be a natural choice for DG as they preserve or increase the accuracy of the DG solution while smoothing the discontinuities inherent to DG schemes [3]. However, these new filtering approaches need to be improved and specifically tailored for a use with LES. In this PhD program, we will adress the development of new high-order filtering methodologies for LES that preserve the accuracy of the DG method, that present a compact stencil to maintain the good parallel efficiency of the simulations, that are computationnally efficient to limit the overall CPU cost of simulations and that address several mathematical peculiarities of the LES formalism, such as the commutation error of the filter with the spatial derivatives or the introduction of a modular physical length scale calibrating the filter width and defining the smallest resolved scales. The work will start with establishing the new filtering strategies using simple one-dimensional equations such as the Burgers equation that allow for modeling the turbulent cascade in a simplified context. The work will then be extended for 3D Navier-Stokes simulation on fully unstructured meshes using the flow solver CODA, which is a collaborative tool developed by Airbus, ONERA and DLR for the simulation of industrial configurations of aeronautical interest. The methodology will be evaluated on cases of increasing complexity in terms of meshes, geometry and turbulent anisotropy, such as decaying isotropic turbulence, turbulent channel flows, turbulent flows over airfoil configurations, ...

[1] Chapelier, J. B., De La Llave Plata, M., Renac, F., & Lamballais, E. (2014). Evaluation of a high-order discontinuous Galerkin method for the DNS of turbulent flows. *Computers & Fluids*

[2] Gullbrand, J., & Chow, F. K. (2003). The effect of numerical errors and turbulence models in large-eddy simulations of channel flow, with and without explicit filtering. *Journal of Fluid Mechanics*

[3] van Slingerland, P., Ryan, J. K., & Vuik, C. (2011). Position-dependent smoothness-increasing accuracy-conserving (SIAC) filtering for improving discontinuous Galerkin solutions. *SIAM Journal on Scientific Computing*

Collaborations envisagées

CODA project – Airbus+DLR

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