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Hybridized methods for compressible and incompressible flows within computational engineering-based digital twins strategies

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ABSTRACT

There is a growing interest in computational engineering-based digital twins for model predictive response to design, optimize and control flow problems. Examples range from Stokes flows (e.g., micro-swimmers such as bioinspired hybrid soft robots) to incompressible (e.g., automotive industry) and compressible (aero) Navier-Stokes. Model-based strategies hinge on computational methods for solving the flow equations. Of course, these algorithms need to be credible and fast. Credible implies the proper accuracy for the problem at hand but also the necessary robustness in order to maintain this accuracy under drastic changes of input. Whereas fast algorithms are concerned both with computer resources and preprocessing time (mostly, mesh generation). This lecture will present and discuss hybridized methods that were originally designed for high-fidelity computations (thus, high-order approximations). In particular, weakly compressible flows coupled with traditional continuous Galerkin models for fluid-structure interaction problems [1] and a unified framework for Riemann solvers (compressible flows) with special emphasis on HLL-type numerical fluxes. The robustness of these Riemann solvers plays a crucial role in presence of supersonic flows due to their positivity-preserving property, which leads to physically meaningful solutions without the need for problem-dependent user-defined corrections [2]. But, despite the growing interest towards high-order methods for CFD, finite volume still represent the standard praxis to model industrial flows, aerodynamics, heat and mass transfer problems. The lecture will also unveil de hybridization procedure within a finite volume methodology. This face-centered finite volume method [3,4] is able to inherit the usual advantages of finite volumes and also demonstrate a robust performance in a wide variety of flow conditions, providing accurate solutions on general unstructured meshes, insensitivity to cell distortion and stretching. The results [5] will showcase the suitability of this method to treat industrial flow problems with complex geometries, relaxing the restrictions of mesh quality imposed by existing finite volume solvers and alleviating the need for time-consuming manual mesh generation procedures performed by specialized technicians.

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