

Physics-Based and Data-Driven Model Order Reduction for Complex Fluid Systems

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ABSTRACT

Model Order Reduction (MOR) techniques have emerged as a key enabler for fast and reliable prediction of complex fluid systems, especially in the context of rapid exploration of the parametric space, which plays a crucial role in a wide range of applications, such as design optimization, control, and development of digital twins. The speaker will present physics-based and data-driven MOR frameworks for two classes of fluid dynamics problems. First, a Proper Orthogonal Decomposition (POD)–Galerkin projection-based model order reduction approach will be demonstrated for a cerebrovascular hemodynamics application to develop a patient-specific digital twin of the vascular system. The incompressible Navier-Stokes equations are projected on a reduced basis. A lifting-function method is used to handle the time-dependent boundary conditions at the inlet, and the predicted flow physics from the MOR approach is compared with the benchmark Computational Fluid Dynamics (CFD) simulation and data-driven models. Next, the speaker will discuss a data-driven framework for fluid-structure interaction at high-speed flows. The Navier-Stokes equations governing aerodynamics are linearized and parameterized by Mach number using a non-intrusive reduced-order model, and coupled with a structural equation to obtain the flutter boundary. The proposed approaches accelerate numerical simulation several-fold and offer potential for next-generation healthcare applications and high-speed aeroelastic design.

ABOUT THE SPEAKER

Dr. Halder is a Post-Doctoral Fellow at the Mathematics Department, International School for Advanced Studies (SISSA), Trieste, Italy. He earned his Bachelor of Engineering from Jadavpur University and Master of Technology from the Indian Institute of Technology, Madras. The speaker completed his PhD at the National University of Singapore, Mechanical Engineering Department in 2020. After that, he worked as a Research Scientist at the Temasek Laboratory, National University of Singapore, and as a postdoctoral fellow at the Active Aeroelasticity and Structures Research Laboratory, University of Michigan Aerospace Engineering Department. The research expertise of Dr. Halder includes the development of various data-driven and physics-based reduced-order models for computational mechanics applications.



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