

FROM HIGH-FIDELITY CFD TO FAST PREDICTIVE MODELS: ROMS AND SCIENTIFIC MACHINE LEARNING

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ABSTRACT

High-fidelity computational fluid dynamics is a key tool for the simulation, analysis, and control of complex flows. However, the associated computational cost remains prohibitive in many-query settings, including parametric studies, uncertainty quantification, inverse problems, optimization, and real-time prediction. Moving from high-fidelity simulations to fast predictive models requires methods that preserve the essential physical and numerical features of the underlying flow dynamics while substantially reducing the computational burden.

This minisymposium focuses on recent advances in reduced-order modeling and scientific machine learning for CFD, with particular emphasis on methods that combine physical structure, numerical accuracy, and data-driven approximation to build fast and reliable surrogate models. Contributions addressing both methodological developments and application-driven challenges are welcome. Topics include projection-based and non-intrusive reduced-order models, reduced basis and POD techniques, empirical interpolation and hyper-reduction, operator learning, physics-informed and structure-preserving learning, neural surrogates for parametric and time-dependent flows, data assimilation, uncertainty quantification, optimization, and control.

Particular attention will be given to the interplay between ROM, SciML, and high-fidelity numerical solvers, including spectral, high-order, discontinuous Galerkin,

and adaptive methods, as well as to applications in realistic flow configurations. Examples of interest include, but are not limited to, turbulent and multiphysics flows, fluid–structure interaction, biomedical flows, environmental and geophysical flows, and industrial or engineering design problems. The minisymposium aims to promote discussion on accuracy, stability, generalization, robustness, and efficiency, with a view toward the reliable use of reduced and data-driven models in real-world CFD applications.

SPEAKERS

1. Patrick J. Blonigan (Sandia National Laboratories): Reduced-basis method-accelerated inverse problems for high-speed aerothermodynamics.
2. Matteo Giacomini (Universitat Politècnica de Catalunya): Coupling high-order methods to reduced order models for the accurate solution of elliptic problems in parameterized geometries.
3. Gianmarco Mengaldo (National University of Singapore): Spatial eigensolution analysis of discontinuous spectral element methods: insights into under-resolved (turbulence) simulations.
4. Anna Maria Ranno (RWTH Aachen University): Hierarchical model reduction combined with a fictitious domain formulation for modeling drug-eluting stents in coronary arteries.
5. Suzanne M. Shontz (University of Kansas): High-order mesh generation based on affine combinations of nodal positions.
6. Erika Temellini (Politecnico di Milano): Hierarchical reduced-order modeling of blood flow in patient-specific vascular geometries.