

HYBRID DATA-DRIVEN AND PHYSICS-BASED COUPLINGS FOR PREDICTIVE DIGITAL TWINS

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ABSTRACT

Recent years have seen a rapid growth in digital twin technologies that integrate simulation, data, and remote sensing to enable predictive, adaptive, and real-time decision-making for complex engineered systems. At the same time, there has been an explosion in the development of data-driven models that can augment or replace expensive high-fidelity simulations, uncover hidden physics, and enable rapid updates as new data become available. These trends motivate the development of hybrid digital twins that couple conventional physics-based models with data-driven components. Such approaches can provide a mechanism to rigorously integrate data-driven models and methods into modeling and simulation toolchains, as well as improve the trustworthiness of data-driven modeling in science and engineering.

Achieving hybrid couplings in a robust and reliable manner raises significant challenges, including consistency across heterogeneous model fidelities, stability of coupled workflows, treatment of nonconforming discretizations, and preservation of key physical structures such as conservation laws, symmetries, and stability properties. This minisymposium will highlight recent advances in methodologies for creating hybrid couplings involving data-driven and conventional models within digital twin frameworks. We welcome submissions featuring a wide range of data-driven approaches, including but not limited to projection-based, operator inference, dynamic mode decomposition and neural network-based reduced order model techniques. Of particular interest are both overlapping and non-overlapping domain decomposition strategies that assign different model types to different regions or physics. Topics of interest include: multi-scale and multi-physics hybrid models, structure-preserving coupling methods, adaptive model switching, optimization-based coupling, iterative schemes such as Schwarz-based methods for information exchange between heterogeneous components, and software frameworks that support heterogeneous model integration.