Seminarvorträge Sommersemester 2024

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Reduced Operator Inference for Nonlinear Partial Differential Equations

Abstract

We present a new scientific machine learning method that learns from data a computationally inexpensive surrogate model for predicting the evolution of a system governed by a time-dependent nonlinear partial differential equation (PDE) an enabling technology for many computational algorithms used in engineering settings. Our formulation generalizes to the PDE setting the Operator Inference method previously developed for systems governed by ordinary differential equations. The method brings together two main elements. First, ideas from projection-based model reduction are used to explicitly parametrize the learned model by low-dimensional polynomial operators which reflect the known form of the governing PDE. Second, supervised machine learning tools are used to infer from data the reduced operators of this physics-informed parametrization. For systems whose governing PDEs contain more general (non-polynomial) nonlinearities the learned model performance can be improved through the use of lifting variable transformations which expose polynomial structure in the PDE. The proposed method is demonstrated on a three-dimensional combustion simulation with over 18 million degrees of freedom for which the learned reduced models achieve accurate predictions with a dimension reduction of six orders of magnitude and model runtime reduction of 5-6 orders of magnitude.