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Learning physics-based reduced-order models from data using nonlinear manifolds

Abstract:

The rapidly increasing demand for computer simulations of complex physical, chemical, and other processes places a significant burden on the shoulders of computational scientists and engineers. Despite the remarkable rise of available computer resources and computing technologies, the need for model order reduction to cope with these problems is an ever-present reality. Reduced-order models are imperative in making computationally tractable outer-loop applications that require simulating systems for many scenarios with different parameters and under varying inputs. They require that one numerically solves the differential equations describing the physical system of interest in low-dimensional reduced spaces, in contrast to the original full-order models. However, traditional model reduction techniques often fail to identify a low-dimensional linear subspace for approximating the solution to many physics-based simulations.

In this talk I will present a novel method for learning projection-based reduced-order models of physics-based dynamical systems using nonlinear manifolds. First, we learn the manifold by identifying nonlinear structure in the data through a general representation learning problem. The proposed approach is driven by embeddings of low-order polynomial form. The algebraic structure of the system that governs the problem of interest in the reduced space is revealed by means of a projection onto the nonlinear manifold. The matrix operators of the reduced-order model are then approximated, in a least-squares sense, using data-driven operator inference. Numerical experiments on a number of nonlinear problems demonstrate the generalizability of the methodology and the increase in accuracy that can be obtained over standard POD-based methods.

Biography:

Rudy Geelen is a postdoctoral researcher working with Karen Willcox at the Oden Institute for Computational Engineering and Sciences. He joined UT Austin as a Peter O'Donnell Postdoctoral Fellow in 2020. Before joining UT Austin, he received a Ph.D. in Mechanical Engineering from Duke University. He holds B.S. and M.S. degrees in Mechanical Engineering from the Eindhoven University of Technology in the Netherlands. He is interested in the broad area of computational science and engineering with a strong focus on computational mechanics, model order reduction and scientific machine learning.