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Bayesian inference for the learning of reduced-state dynamics

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In this talk, we discuss the incorporation of Bayesian inference into the data-driven operator inference [1] framework, a non-intrusive approach to the reduced order modeling of time-dependent partial differential equations. Inspired by the polynomial structure of projection-based, reduced-state governing equations, a reduced model is learned using linear Bayesian inference with Gaussian priors [2]. The reduced-order operators are recovered as posterior Gaussian distributions conditioning on the projected state data onto a POD basis. Through time integration, such probabilistic variation is propagated to the reduced-order solutions for which uncertainty bounds are formulated. Compared to the deterministic operator inference that only gives point estimates, the proposed Bayesian version quantifies the modeling uncertainties in the constructed reduced system. As a Tikhonov regularization is embedded in the Bayesian operator inference, an updating algorithm for the selection of regularization parameters is suggested based on the empirical Bayes method of maximum marginal likelihood. The proposed method works as a 'grey-box', data-driven model reduction scheme, which inherits the basic physics but does not require access to the full-order solvers, and provides new perspectives of regularized operator inference [3] and its uncertainty quantification. The effectiveness of Bayesian operator inference is shown in the reduced order modeling of an Euler system corrupted by significant noise and a single-injector combustion process featuring complex physics. We will also briefly discuss the options of using Bayesian inference for the deep-learning-based recovery of reduced-state dynamics.

This is joint work with S. A. McQuarrie (UT Austin), K. E. Willcox (UT Austin), et al.

REFERENCES

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