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IMPROVING ACCURACY OF STOCHASTIC COLLOCATION SURROGATES FOR ODE/PDE SYSTEMS VIA DATA-DRIVEN FACTORIZATION OF MODEL DYNAMICS

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ABSTRACT

Stochastic collocation (SC) is a popular framework for constructing surrogates of expensive computational models, and it is often used in uncertainty quantification (UQ) tasks. It approximates quantities of interests (QoIs), via interpolation over the stochastic parameter dimensions, using data generated from a few exact simulations in a non-intrusive and online fashion; this approach is very easy to implement in existing numerical codes. However, as the nonlinearity of the parameter-to-QoI maps increase, the accuracy of the approximations degrades rapidly.

In the context of forward uncertainty propagation (forward UQ) in systems governed by ODEs/PDEs with uncertain parameters, we propose to improve the accuracy of SC by directly approximating the dynamics, rather than targeting the system states or other derived QoIs. We hypothesize that the parameter-to-dynamics map is typically much simpler when compared to the parameter-to-state map, therefore the dynamics should be easier to approximate using low-order SC surrogates. In order to construct the approximation, we use a data-driven factorization of the model dynamics that decouples the model state from the stochastic parameters, and learn the factors from simulated exact trajectories. We then apply SC to the stochastic parameter dependent factor to construct the surrogate dynamics, and evolve the corresponding approximate systems. With this minimal intrusion, we demonstrate that our approach reduces approximation errors by several orders of magnitudes when applied to the chaotic Lorenz ODE system, and finite element simulations of continuum solid mechanics PDE system.

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