A model reduction approach for partitioned treatment of uncertainty in coupled problems

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ABSTRACT

The uncertainty quantification (UQ) of coupled systems, such as those involving multiple interacting components (or physics/scales) is challenged by two major difficulties: Firstly, the presence of independent uncertainty sources within different component models results in a combined high-dimensional stochastic space which may not be amenable to computation using standard approaches, e.g., sampling in the combined dimensions. Secondly, single component solvers are often separate modules that may not have access to detailed information from one another, thus limiting the applicability of a large class of UQ strategies. To address the above challenges, in this work, we propose a stochastic model reduction framework, within the context of low-rank separated (canonical) decompositions, for a partitioned treatment of the uncertainty space. In particular, the propagation of uncertainty across the interacting components is accomplished by expanding the field quantities in a stochastic basis that is constructed adaptively and by calling the component solvers one at a time. The key novelty of the proposed approach is that the propagation of uncertainty is achieved though a sequence of approximations with respect to the dimensionality of each individual component and not the combined dimensionality. This allows the method to scale better than the standard UQ approaches.