A Study of Hybrid Uncertainty Quantification Methods With an Application to Reaction Diffusion Equations

Project Title: High Performance Embedded Hybrid Methodology for Uncertainty Quantification in Multi-physics Problems

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Abstract

In this talk we will first present an overview of a hybrid intrusive/non-intrusive uncertainty quantification (UQ) methodology for multi-physics applications. There are many forms of hybrid UQ methods. The focus of our investigation is on "divide-and-conquer" approach which allows independent development of uncertainty propagation schemes in each physics component of subsystem. The flow of uncertainties across physics components will be handled by a generic computational framework which ensures relevant 'global uncertainties' are captured accurately. This "plug-and-play" philosophy aligns well with the modern multi-physics simulation software development practice which offers more flexibility and higher productivity. To develop such a hybrid computational framework, we envison many challenges including the proper inter-component uncertianty representations, error analysis, dimension reduction, data fusion, achieving high efficiency on high performance computers, etc.

After a brief introduction of the methodology, we will describe a representative example of our hybrid UQ development. Specifially, we will present the analysis of an algorithm for propagating global uncertainties through an "operator-splitted" reaction diffusion solver where the diffusion module is solved using intrusive polynomial chaos and the reaction module is solved using non-intrusive sampling method. We will discuss how the treatment of uncertainties can be decoupled between the two modules. We will present numerical results comparing this approach with purely intrusive and sampling methods. We will also describe the application of this algorithm to a more realistic multi-species reactive transport problem. Finally, We will analyze the parallel efficiency of this algorithm.