A multi-fidelity method for uncertainty quantification in engineering problems

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Computer simulations, which are nowadays a fundamental tool in every field of science and engineering, need to be fed with parameters such as physical coefficients, initial states, geometries, etc. This information is however often plagued by uncertainty: values might be e.g. known only up to measurement errors, or be intrinsically random quantities (such as winds or rainfalls). Uncertainty Quantification (UQ) is a research field devoted to dealing efficiently with uncertainty in computations. UQ techniques typically require running simulations for several (carefully chosen) values of the uncertain input parameters (modeled as random variables/fields), and computing statistics of the outputs of the simulations (mean, variance, higher order moments, pdf, failure probabilities), to provide decision-makers with quantitative information about the reliability of the predictions. Since each simulation run typically requires solving one or more Partial Differential Equations (PDE), which can be a very expensive operation, it is easy to see how these techniques can quickly become very computationally demanding.

In recent years, multi-fidelity approaches have been devised to lessen the computational burden: these techniques explore the bulk of the variability of the outputs of the simulation by means of low-fidelity/low-cost solvers of the underlying PDEs, and then correct the results by running a limited number of high-fidelity/high-cost solvers. They also provide the user a so-called "surrogate-model" of the system response, that can be used to approximate the outputs of the system without actually running any further simulation.

In this talk we illustrate a multi-fidelity method (the so-called multi-index stochastic collocation method) and its application to a couple of engineering problems. If time allows, we will also briefly touch the issue of coming up with good probability distributions for the uncertain parameters, e.g. by Bayesian inversion techniques.

References

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