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APPLIED MATHEMATICS SEMINAR 291

"Mean-variance Risk-averse Optimal Control of Systems Governed by PDEs with Random Parameter Fields Using Quadratic Approximations"

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ABSTRACT

We present a method for optimal control of systems governed by partial differential equations (PDEs) with uncertain parameter fields. We consider an objective function that involves the mean and variance of the control objective, leading to a risk-averse optimal control problem. To make the optimal control problem tractable, we invoke a quadratic Taylor series approximation of the control objective with respect to the uncertain parameter field. This enables deriving explicit expressions for the mean and variance of the control objective in terms of its gradients and Hessians with respect to the uncertain parameter. The risk averse optimal control problem is then formulated as a PDE-constrained optimization problem with constraints given by the forward and adjoint PDEs defining these gradients and Hessians. The expressions for the mean and variance of the control objective under the quadratic approximation involve the trace of the (preconditioned) Hessian, and are thus prohibitive to evaluate. To overcome this difficulty, we employ randomized trace estimators. We illustrate our approach with two specific problems: the control of a semi linear elliptic PDE with an uncertain boundary source term, and the control of a linear elliptic PDE with an uncertain coefficient field. For the latter problem, we derive adjoint-based expressions for efficient computation of the gradient of the risk-averse objective with respect to the controls. Our method ensures that the cost of computing the risk averse objective and its gradient with respect to the control-measured in the number of PDE solves-is independent of the (discretized) parameter and control dimensions, and depends only on the number of random vectors employed in the trace estimation. Finally, we present a comprehensive numerical study of an optimal control problem for fluid flow in a porous medium with uncertain permeability field.

This research is joint work with Alen Alexanderian (NC State), Georg Stadler (NYU), and Omar Ghattas (UT Austin)

BIO:

Noemi Petra is an assistant professor of Applied Mathematics in the School of Natural Sciences at the University of California, Merced. She is currently also the secretary of the SIAM Uncertainty Quantification Activity Group (SIAM UQ) and the faculty advisor of the UC Merced SIAM Student Chapter. Noemi earned her B.Sc. degree in mathematics and computer science from Babes-Bolyai University, Romania, and her Ph.D. degree in applied mathematics from the University of Maryland, Baltimore County. Prior to joining the University of California, Merced she was the recipient of an ICES (Institute for Computational Engineering & Sciences) Postdoctoral Fellowship at the University of Texas at Austin. During Summers 2015 and 2016, she was a Visiting Faculty in the Mathematics and Computer Science Division at Argonne National Laboratory, funded by the Department of Energy (DOE) Visiting Faculty Program (VFP). Her research interests include large-scale inverse problems governed by differential equation, uncertainty quantification in inference and prediction, and optimal experimental design.