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“Active subspace methods in theory and practice: Does your model really have lots of parameters?”

Abstract:

Science and engineering models typically contain multiple parameters representing input data---e.g., boundary conditions or material properties. The map from model inputs to model outputs can be viewed as a multivariate function. One may naturally be interested in how the function changes as inputs are varied. However, if computing the model output is expensive given a set of inputs, then exploring the high-dimensional input space is infeasible. Such issues arise in the study of uncertainty quantification, where uncertainty in the inputs begets uncertainty in model predictions.

Fortunately, many practical models with high-dimensional inputs vary primarily along only a few directions in the space of inputs. I will describe a method for detecting and exploiting these directions of variability to construct a response surface on a low-dimensional linear subspace of the full input space; detection is accomplished through analysis of the gradient of the model output with respect to the inputs, and the subspace is defined by a projection. I will show error bounds for the low-dimensional approximation that motivate computational heuristics for building a kriging response surface on the subspace. As a demonstration, I will apply the method to a nonlinear heat transfer model on a turbine blade, where a 250-parameter model for the heat flux represents uncertain transition to turbulence of the flow field. I will also discuss the range of existing applications of the method---including the motivating application from Stanford's NNSA PSAAP center---and the future research challenges.

Speaker Bio:

Paul Constantine is the Ben L. Fryrear Assistant Professor of Applied Mathematics and Statistics at Colorado School of Mines. He received his Ph.D. in 2009 from Stanford's Institute for Computational and Mathematical Engineering and was awarded the John von Neumann Research Fellowship at Sandia National Labs. Paul's interests include methods for dimension reduction and reduced order modeling in the context of uncertainty quantification.

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