Cornell University

Civil and Environmental Engineering

Data driven strategies for constructing reduced-order stochastic models of random heterogeneous media

Rm. 366 Hollister Hall
Monday, November 12, 4:30 PM

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In recent years, there has been intense interest in understanding various physical phenomena in random heterogeneous media. Any accurate description/simulation of a process in such media has to satisfactorily account for the inherent randomness in the material properties. An accurate model of the material property variation in the system is an important prerequisite towards complete characterization of the system response. Two general methodologies to construct data-driven, reduced-order models to describe property variations in realistic heterogeneous media are discussed. Given only some statistical information about the property distribution (like two-point correlation functions and size distribution functions), these frameworks construct a reduced-order stochastic representation of the property variation. The first framework is based on the well known concept of proper-orthogonal-decomposition (POD). Limited information is converted into a set of basis functions that describe the property variability as a linear space. The second framework extends this POD framework to capture non-linear features of the property variability. The problem of constructing low-dimensional stochastic representations of property variation is shown to be analogous to the problem of manifold learning and parametric fitting of hypersurfaces encountered in image processing and psychology. The developed strategies are illustrated by modeling physical processes on random heterogeneous microstructure.

The strategies developed have direct applicability to problems where working in high-dimensional spaces is computationally intractable, for instance, in visualization of property evolution, extracting process-property maps in low dimensional spaces, among others. Furthermore, the generation of a low-dimensional surrogate space has major ramifications in the optimization of properties-processes and structures, making complicated operations like searching, contouring and sorting computationally feasible.

Civil Infrastructure Seminar
Supported by the
Charles L. Crandall Fund

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