CECE Seminar

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Bayesian Uncertainty Quantification Framework for Complex Models in Structural Dynamics

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Bayesian inference is used for quantifying and calibrating uncertainty models in structural dynamics based on vibration measurements, as well as propagating these uncertainties in simulations for updating robust predictions of system performance, reliability and safety. The Bayesian tools for identifying system and uncertainty models as well as performing robust prediction analyses are Laplace methods of asymptotic approximation and sampling algorithms. These tools involve solving optimization problems, generating samples for tracing and then populating the important uncertainty region in the parameter space, as well as evaluating integrals over high-dimensional spaces of the uncertain model parameters. They require a moderate to very large number of system re-analyses to be performed over the space of uncertain parameters. Consequently, the computational demands depend highly on the number of system analyses and the time required for performing a system analysis.

A computational framework for Bayesian uncertainty quantification and propagation for complex models in structural dynamics will be presented. The model complexity is due to the very high number (hundreds of thousands or millions) of degrees of freedom arising in developing high-fidelity structural models, the localized nonlinear actions activated during system operation, and the applied stochastic loads. High performance computing techniques are integrated with Bayesian techniques to efficiently handle such complexities. Fast and accurate component mode synthesis (CMS) techniques are proposed, consistent with the finite element model parameterization, to achieve drastic reductions in computational effort. Surrogate models are also used within multi-chain sampling algorithms with annealing properties to substantially speed-up computations, avoiding full system re-analyses. Significant computational savings are achieved for stochastic simulation algorithms by adopting parallel computing algorithms to efficiently distribute the computations in available GPUs and multi-core CPUs. Important issues related to the computational efficiency of the asymptotic approximations versus the stochastic simulation algorithms for serial or parallel computing environments are discussed. Applications of the framework to structural health monitoring, damage identification and updating the remaining structural reliability are emphasized. The proposed approach is demonstrated using applications in civil infrastructure and vehicle dynamics.