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Fast Bayesian estimators for structural damage identification using vibration measurements

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Abstract:

Bayesian estimators are proposed for damage identification (localization and severity) of civil infrastructure using vibration measurements. Damage occurring at one or more structural components can be monitored by updating a family of parameterized finite element (FE) model classes, with the members in the model class family introduced to monitor a large number of potential damage scenarios covering critical parts of the structure. Bayesian inference is used to rank the plausible damage scenarios according to the posterior probability of the corresponding parameterized FE model classes. The most probable FE model class is indicative of the location of damage, while the severity of damage is inferred from the posterior probability of the model parameters of the most probable model class.

To reliably estimate damage, high fidelity model classes, often involving hundred of thousands of DOFs, are introduced to simulate structural behavior. The proposed Bayesian estimators, based on asymptotic approximations and/or efficient stochastic simulation techniques, require a large number of full FE model simulations to be carried out, imposing severe computational limitations on the application of the damage identification technique. The computational demands depend highly on the number of full model re-analyses and the time required for performing a system analysis. HPC techniques are integrated with Bayesian techniques to efficiently handle large-order models of hundreds of thousands or millions degrees of freedom and localized nonlinear actions activated during system operation. Fast and accurate component mode synthesis techniques, consistent with the FE model parameterization, are proposed to achieve drastic reductions in computational effort. Further computational savings are achieved by adopting surrogate models (e.g. kriging techniques) to reduce the number of full model simulations, and parallel computing algorithms to efficiently distribute the computations in available multi-core CPUs. The effectiveness of the damage identification methodology is illustrated using simulated damage scenarios from a real bridge. It is demonstrated that the proposed methodology correctly identifies the location and severity of damage. Remarkable reductions in computational effort are achieved by the proposed fast Bayesian estimators.

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