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“Bayesian Uncertainty Quantification and Optimal Experimental Design in Data-driven Simulations of Engineering Systems”

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Περίληψη: The objective of this thesis is twofold. First, Bayesian uncertainty quantification, propagation, and model selection theories are outlined and applied to real-world problems, and second, Bayesian optimal experimental design theories are studied from a theoretical point of view and also applied to numerical case-studies. The Bayesian theory for uncertainty quantification, propagation and model selection is first presented and computational challenges are discussed. The Bayesian formulation is applied to three case-studies taken from real-world applications, using experimental data collected from field tests. It is demonstrated how the Bayesian theories can be applied to such real scale problems of model updating and model selection to draw useful conclusions about the systems under consideration. The examined problems include: 1) Model updating and model selection in a hanger of an arch bridge using modal data obtained from acceleration measurements. 2) Model updating of a bridge using a high-fidelity finite element model utilizing experimentally identified modal data. The modal data are extracted from ambient acceleration measurements using a software developed in the context of this thesis. 3) Parameter estimation of non-linear models of seismically isolated bridges using experimentally measured response time histories from the bridge. Next the theory of Information Theoretic - Bayesian optimal experimental design is developed. Two approaches are developed for the estimation of the objective function, the sampling and asymptotic approaches. Novel theoretical contributions are developed in both approaches, providing further insight into the problem of Bayesian optimal experimental design. The theories of optimal experimental design are applied to numerical case-studies using finite element models. The asymptotic approach is applied to design the optimal locations of acceleration sensors on a bridge in order to perform modal identification, while it also demonstrates the theoretical findings in the particular problem. Next a joint study is presented in both Bayesian parameter estimation and Bayesian optimal experimental design, where the newly developed sampling approach is used to find the optimal locations of strain sensors in a plate with crack under static loading.

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