Bayesian Identification of Nonlinear Structural Systems: Innovations to Address Practical Uncertainty

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The ability to rapidly assess the condition of a structure in a manner which enables the accurate prediction of its remaining capacity has long been viewed as a crucial step in allowing communities to make safe and efficient use of their public infrastructure. This objective has become even more relevant in recent years as both the interdependency and state of deterioration in infrastructure systems throughout the world have increased. Current practice for structural condition assessment emphasizes visual inspection, in which trained professionals will routinely survey a structure to estimate its remaining capacity. Though these methods have the ability to monitor gross structural changes, their ability to rapidly and cost-effectively assess the detailed condition of the structure with respect to its future behavior is limited.

Vibration-based monitoring techniques offer a promising alternative to this approach. As opposed to visually observing the surface of the structure, these methods judge its condition and infer its future performance by generating and updating models calibrated to its dynamic behavior. Bayesian inference approaches are particularly well suited to this model updating problem as they are able to identify the structure using sparse observations while simultaneously assessing the uncertainty in the identified parameters. However, a lack of consensus on efficient methods for their implementation to full-scale structural systems has led to a diverse set of Bayesian approaches, from which no clear method can be selected for full-scale implementation. The objective of this work is therefore to assess and enhance those techniques currently used for structural identification and make strides toward developing unified strategies for robustly implementing them on full-scale structures. This is accomplished by addressing several key research questions regarding the ability of these methods to overcome issues in identifiability, sensitivity to uncertain experimental conditions, and scalability. These questions are investigated by applying novel adaptations of several prominent Bayesian identification strategies to small-scale experimental systems equipped with nonlinear devices. Through these illustrative examples I explore the robustness and practicality of these algorithms, while also considering their extensibility to higher-dimensional systems. Addressing these core concerns underlying full-scale structural identification will enable the practical application of Bayesian inference techniques and thereby enhance the ability of communities to detect and respond to the condition of their infrastructure.