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BAYESIAN OPTIMAL SENSOR PLACEMENT FOR VIRTUAL SENSING AND STRAIN RECONSTRUCTION

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Designing an appropriate sensor network for structural health monitoring has great significance in maximizing the useful information contained in the experimental data. Optimal sensor placement (OSP) strategies can be used to provide the critical information needed for model selection, parameter estimation, structural damage identification and virtual sensing of unmeasured output quantities of interest (QoI) using output-only vibration measurements. It also contributes to decision-making processes related to maintenance actions.

In this study, a Bayesian OSP framework is presented for virtual sensing in structures using output-only vibration measurements. Particularly, this probabilistic OSP scheme aims to enhance the reconstruction of dynamical responses (e.g., accelerations, displacements, strain, stresses) for updating structural reliability and safety, as well as fatigue lifetime prognosis. The OSP framework is formulated using information and utility theories. The utility function is defined as the Kullback-Liebler divergence (KL-div) between the prior and posterior distributions of the response QoI. The Gaussian nature of the response estimate for linear models of structures is employed, and the utility function is characterized in terms of the reconstruction error covariance matrix. A Kalman-based input-state estimation technique [1] is integrated within an existing OSP strategy [2], aiming to obtain estimates of response QoI and their uncertainties. The design variables include the location, type and number of sensors. As a result, robustness issues are discussed by extending the utility function to account for structural modeling, input variability and prediction error uncertainties. Genetic algorithm (GA) and heuristic algorithms are used to solve optimization problem and provide computationally efficient solutions. The effectiveness of the method is demonstrated using examples from structural dynamics.

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