Bayesian Structural Identification with Systematic Uncertainty Using Multiple Responses

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Abstract : Structural health monitoring is one of the most promising technologies concerning aversion of structural risk and economic savings. Analysts often have to deal with a considerable variety of uncertainties that arise during a monitoring process. Namely the widespread application of numerical models (model-based) is accompanied by a widespread concern about quantifying the uncertainties prevailing in their use. Some of these uncertainties are related with the deterministic nature of the model (code uncertainty) others with the variability of its inputs (parameter uncertainty) and the discrepancy between a model/experiment (systematic uncertainty). The actual process always exhibits a random behaviour (observation error) even when conditions are set identically (residual variation). Bayesian inference assumes that parameters of a model are random variables with an associated PDF, which can be inferred from experimental data. However in many Bayesian methods the determination of systematic uncertainty can be problematic. In this work systematic uncertainty is associated with a discrepancy function. The numerical model and discrepancy function are approximated by Gaussian processes (surrogate model). Finally, to avoid the computational burden of a fully Bayesian approach the parameters that characterise the Gaussian processes were estimated in a four stage process (modular Bayesian approach). The proposed methodology has been successfully applied on fields such as geoscience, biomedics, particle physics but never on the SHM context. This approach considerably reduces the computational burden; although the extent of the considered uncertainties is lower (second order effects are neglected). To successfully identify the considered uncertainties this formulation was extended to consider multiple responses. The efficiency of the algorithm has been tested on a small scale aluminium bridge structure, subjected to a thermal expansion due to infrared heaters. Comparison of its performance with responses measured at different points of the structure and associated degrees of identifiability is also carried out. A numerical FEM model of the structure was developed and the stiffness from its supports is considered as a parameter to calibrate. Results show that the modular Bayesian approach performed best when responses of the same type had the lowest spatial correlation. Based on previous literature, using different types of responses (strain, acceleration, and displacement) should also improve the identifiability problem. Uncertainties due to parametric variability, observation error, residual variability, code variability and systematic uncertainty were all recovered. For this example the algorithm performance was stable and considerably quicker than Bayesian methods that account for the full extent of uncertainties. Future research with real-life examples is required to fully access the advantages and limitations of the proposed methodology.

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