Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Sensitivity Analysis of a Complex Multibody System



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Clusters
Lichtenberg Cluster Darmstadt

Software
MATLAB

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Introduction

This project was a follow-up project for our initial project intended at setting up Lichtenberg Cluster for the use within our research projects at the research group System Reliability, Adaptive Structures, and Machine Acoustics. The frame of this project application is the DFG project “Efficient statistical parameter calibration for complex structural dynamics systems under consideration of model uncertainty” (Project number 460838752). Within this project, the demonstrator of the Collaborative Research Center 805 (“Control of Uncertainty in Load-Carrying Structures in Mechanical Engineering”) undergoes statistical model calibration to improve its predictive capability. Precise models are of paramount importance in the virtualization of the modern industrial product development process, since they help replacing the costly development of prototypes and support in the decision-making process. In preparation for the statistical model calibration, a sensitivity analysis has been conducted, that quantifies how much variation in the model outputs can be attributed to the variation in the respective model parameters. This information helps identifying influential and non-influential model parameters in order to reduce the number of model parameters in subsequent model calibration by fixing model parameters without influence.

Methods

There are two prominent approaches to sensitivity analysis: variance-based methods, such as Sobol Indices, and screening methods, such as Morris screening. Screening methods rank the parameters according to their influence on the model outputs

and are computationally less expensive than variance-based methods, but unlike variance-based methods they do not quantify the influence in general [2]. We computed the Sobol indices used the Toolbox UQLAB by ETH Zurich [1]. Sobol indices are based on the expansion of the model into summands of increasing dimension, where the total variance of the model is described by the sum of the variances of the summands. There are multiple available estimators for the estimation of the Sobol indices. We first tried a computationally less expensive estimator of Saltelli, but the results were not convincing. We then tried the computationally more expensive estimator of Homma and found results that were meaningful in a physical sense.

Results

The results of the sensitivity analysis were as expected. The relevant model parameters could be identified and the results were plausible. The Sobol indices for four model outputs in Figure 1. Only four out of 13 model parameters are found to have an influence of the model outputs. This entails a significant simplification of subsequent model calibration, since the number of model parameters to be calibrated is only about a third of the original number of model parameters. We also found that the results shown in Figure 1 greatly depend on the assumed variation range of the model parameters. This underlines the importance of adequate prior knowledge of realistic model parameter ranges.

Discussion

Based on the results achieved within this project, we could continue as planned with the working program of our DFG project. Using the results of this project, we could successfully apply our developed method for efficient statistical model calibration on the demonstrator of the Collaborative Research Center 805

Reference

[1] Marelli, S.; Sudret, B.: "UQLAB: A framework for Uncertainty Quantification in MATLAB." in Beer, M; Au, S.-K.; Hall, J.W. (Eds.): "Vulnerability, Uncertainty, and Risk. Quantification, Mitigation, and Management." ASCE American Society of Civil Engineers: American Society of Civil Engineers, pp. 2554–2563, (2014) https://doi.org/10.1061/9780784413609.257

[2] Smith, R.C,: "Uncertainty quantification: Theory, Implementation, and Applications." Vol. 12, Computational Science & Engineering, Philadelphia, Pa.: SIAM Society for Industrial and Applied Mathematics, (2014) https://my.siam.org/Store/Product/viewproduct/?ProductId=24973024

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