University of Stuttgart
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Announcement – Master's Thesis

Uncertainty quantification and sensitivity analyses for FEM-based models

Motivation: The Finite Element Method (FEM) is a well-established and robust technique widely used for solving complex physical phenomena across various disciplines. However, when modeling real-world systems, uncertainties in the model parameters and boundary conditions cannot be entirely eliminated. These uncertainties can arise from various sources, such as modeling errors, measurement inaccuracies, variability of material properties, or imprecise input data. Considering uncertainties is of paramount importance to make realistic and reliable predictions. The Bayesian approach has proven to be an elegant method for integrating probabilities into statistical estimations and quantifying uncertainties. The combination of the Bayesian approach with Fuzzy arithmetic also allows for modeling vagueness and epistemic uncertainty, providing additional flexibility in the modeling process. The collaboration with partners in the project DigiTain and the analysis of uncertainties within the framework of the BMWK project on "New Vehicle and System Technologies"present a unique opportunity to vividly demonstrate the practical relevance and applicability of the developed approach.

Tasks: How can the integration of a Bayesian approach with Fuzzy arithmetic be effectively developed and implemented in practical applications to accurately quantify and address uncertainties in various FEM-based models?

[Quelle: DigiTain, BMWK-Vorstellung, Mercedes-Benz AG]

Procedure: A methodology is developed to estimate the posterior distribution of model parameters in a given FEM model structure using the Bayes' theorem, the likelihood function, and Fuzzy arithmetic. This approach identifies possible uncertainties and vagueness in the model parameters, boundary conditions, and material properties. Subsequently, the likelihood function is formulated to evaluate the agreement between the FEM model and real observations. Combining prior distributions of parameters with the Bayesian approach, the uncertainties are quantified, and the posterior distribution of model parameters is determined. The developed methodology is applied to a specific FEM model in the field of vehicle and system technologies.

Requirements: Ideally, candidates should possess experience in numerical simulation and be familiar with the functioning of FEM-based models. The implementation of the developed methodology will require programming skills, with knowledge of languages like Python, MATLAB, or similar being advantageous for conducting numerical computations. A solid background in statistics, probability, uncertainty analysis, and Fuzzy arithmetic is beneficial, as these concepts will be applied in the Master's thesis. However, there is also an opportunity for candidates to learn and deepen their understanding of these topics during the research process to meet the specific demands of the study effectively.

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