Uncertainty Quantification in FE Analyses with Surrogate Modeling

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Module number	**Credits**	**Workload**	**Semester[s]**	**Duration**	**Group size**
BI-WP58/CE-WP29/SE-O-17	6 CP	180 h	3. Sem.	1 Semester[s]	no limitation

Courses	**Contact hours**	**Self-study**	**Frequency**
a) Uncertainty Quantification b) Surrogate Modeling	a) 2 WLH (30 h) b) 2 WLH (30 h)	a) 60 h b) 60 h	a) each winter b) each winter

Module coordinator and lecturer(s)

Prof. Dr. Roger A. Sauer
a) Dr.-Ing. Gerrit E. Neu
b) Dr.-Ing. Ba Trung Cao

Admission requirements

Recommended previous knowledge:
Fundamental knowledge in structural analysis, Finite Element Method, probability theory, and basic programming (MATLAB, Python)

Learning outcome, core skills

The course equips students with theoretical foundations and practical skills to model, propagate, and mitigate uncertainties in structural analysis. Students will be able to define an uncertainty quantification problem, evaluate the effect of aleatory, epistemic as well as polymorphic uncertainty onto computational models and to interpret the results. It delves into surrogate modeling methods that approximate high-fidelity simulations, enabling efficient uncertainty assessment in complex systems. Applications to structural reliability, optimization, and risk-informed decision-making are emphasized, with hands-on experience using state-of-the-art computational tools.

After successfully completing the modules, the students are able to

- Understand the role and significance of uncertainty in structural engineering and computational models.
- Apply probabilistic and non-probabilistic methods for modeling uncertain parameters.
- Develop and implement surrogate models for efficient uncertainty propagation and sensitivity analysis.
- Use state-of-the-art tools and frameworks to solve real-world problems involving uncertain data.

Contents

a)
The course deals with the uncertain data involving in structural analysis:

- Fundamentals of uncertainty quantification: types and sources of uncertainty (aleatory vs. epistemic)
- Sources of uncertainty in structural engineering: material properties, geometry, boundary conditions, and external loads
- Computing with uncertainty models: stochastic model, interval analysis, fuzzy logic, and polymorphic model
- Evaluation of model responses due to uncertain inputs: Quantification by statistical measures, sensitivity analysis and structural reliability

b)

The course deals with the development of numerical surrogate models to accelerate the computation with uncertain data:

- Surrogate models based on black-box machine learning techniques (Artificial Neural Network)
- Surrogate models based on reduced order methods (Proper Orthogonal Decomposition)
- Surrogate models based on hybrid combination (Physics-informed machine learning)
- Comparison of surrogate modelling techniques: accuracy vs. computational efficiency

Educational form / Language

a) Lecture (2 WLH) / English
b) Lecture (2 WLH) / English

Examination methods

• Term paper 'Uncertainty Quantification in FE Analyses with Surrogate Modeling' (90 h., Part of modul grade 100 %, Final project assignment + presentation of the results is used to determine the final grade Deadline will be announced at the beginning of the semester.)

Requirements for the award of credit points

- Passed final module examination

Module applicability

- M.Sc. Civil Engineering
- M.Sc. Subsurface Engieering
- M.Sc. Computational Engineering

Weight of the mark for the final score

Percentage of total grade [%] = 6 * 100 * FAK / DIV
FAK: The weighting factors can be taken from the table of contents.
DIV: The values can be taken from the table of contents.

Further Information