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Calibrating turbulence model parameters with adaptive surrogate models

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For the purpose of fatigue modeling of offshore wind turbines, understanding the main sources of uncertainty is highly relevant. Prominent examples of uncertain parameters include for example those that describe uncertain weather conditions. These uncertainties have to be taken into account during the design and planning phase of the wind turbine installation to ensure the reliability of the wind turbine during its lifetime. Besides known sources of uncertainty, a different type of uncertainty comes from the errors and assumptions in the models used for the prediction, which are often not known explicitly. In this talk, the focus is mainly on the latter type.

A popular approach to capture the uncertainty in the model is to calibrate it using measurement data and techniques from Bayesian statistics. This is often called Bayesian model calibration. The numerical techniques for Bayesian calibration are often too computationally expensive if complex models are involved. Each evaluation of the posterior requires an evaluation of the computationally expensive model. The canonical approach to sample from the posterior is to use Markov chain Monte Carlo techniques, but these techniques require a prohibitively large number of discrete model evaluations. There exist various approaches to reduce the number of required evaluations, but for the applicability to complex computational fluid dynamics cases (as used in the field of wind energy) a larger reduction is necessary.

In this talk, a different approach is proposed and discussed. Instead of replacing the sampling procedure, the expensive model is replaced with a computationally cheaper surrogate model of polynomial form. To reduce the number of model evaluations even further, the surrogate model is adaptively constructed using interpolatory Leja nodes.

The adaptive surrogate relies on iteratively refining an interpolatory polynomial such that the posterior, generated with this polynomial, converges to the "true" posterior. The posterior gives a probability distribution of the model parameters, quantifying the uncertainty associated with the model. We use this approach to calibrate the models that are used for calculating the aerodynamic loading on wind turbine blades. Specifically, we use experimental data to calibrate the closure parameters of the Spalart-Allmaras turbulence model for the fluid flow over an airfoil. The resulting calibrated model is then used to make predictions under uncertainty, with the potential to improve the design and reliability of the turbine blades.