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Well-founded meta modeling of wind turbines

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1 Introduction

The simulation of wind turbines is very time-consuming as many load cases have to be calculated due to controller-induced nonlinearities. Furthermore, simulation models of wind turbines are stochastic, e.g. wind loads, leading to an increase in simulation time. Especially in case of structural optimization or probabilistic analyses, time-domain simulations are hardly possible anymore.

An alternative to time-domain simulations is the use of meta models approximating the relation of input and output variables without considering the physical background. Recently, meta models have already been used in the wind energy sector. However, an assessment of whether the most suitable meta model is used, is rarely conducted. Moreover, comprehensive investigations of training data for meta models are not performed. This means, that neither the amount of training data nor the positioning in the parameter space nor the sampling method are analyzed more precisely, although all these aspects have a considerable influence on the quality of the meta model [1]. A first step in this direction was made in Dimitrov et al. [2].

2 Project outline

The aim of this project is a comprehensive consideration of meta modeling of wind turbines. To use meta models in the best possible way, it is mandatory to execute an extensive comparison of available meta models and the related sampling methods. The number of model inputs, the degree of nonlinearity, or the stochastic model behavior can significantly influence the accuracy of the meta model. Therefore, existing meta models that have proven suitable for other applications cannot simply be adopted.

2.1 Meta models

Different meta models will be investigated. We focus on meta models that have already been used in the wind energy sector, e.g. neural networks, Kriging, polynomial chaos expansion, and multiple regressions.

2.2 Sampling methods

Training and test data will be generated using various sampling procedures. Alternatives to frequently used but inefficient methods, e.g. Monte Carlo simulation, will be investigated. It is planned to consider space-filling techniques (e.g. Sobol' sequences), methods, that focus samples on important areas (e.g. importance sampling), and adaptive techniques. Training and test data will be generated with the simulation software FAST [3].

2.3 Evaluation and comparison procedure

The meta models will be evaluated and compared on the basis of three criteria. The first and most important criterion is physical plausibility. Meta models must provide physically meaningful results in

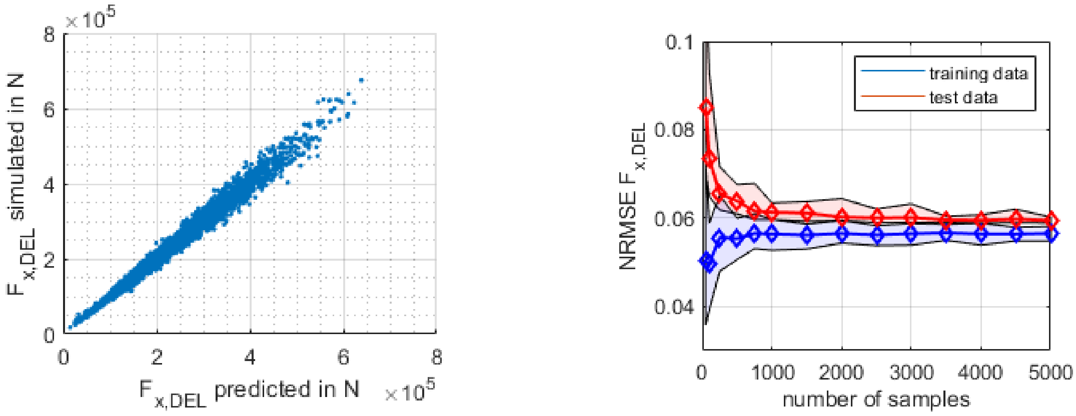

Figure 1: (a) Comparison of simulation and prediction for test data (b) Convergence of Kriging with respect to the number of samples used for training the model (NRMSE normalized root-mean-square error)

relevant areas in order to replace the full simulation model. The second criterion is the approximation quality. Test data should be used for determining the quadratic approximation error. The third criterion is the calculation time. The calculation time of the meta model is usually not relevant, but only the calculation time for the generation of the meta model. The generation time of a meta model for a time-consuming, complex simulation model is significant affected by the amount of training data.

3 Current work and first results

The first investigations are carried out for the meta model Kriging, since Kriging is already used in the wind energy sector and leads to good results [2]. The structural model represents the NREL 5MW turbine with the OC3 monopile and soil [4] and with environmental conditions measured at the FINO 3 research platform [5]. The wind speed, significant wave height and peak period of the waves are considered as random variables. The loads at mudline and at the rotor blade root are evaluated.

First results show that a good approximation of the simulated data can be achieved using the Kriging meta model (see Figure 1(a)). Another preliminary result is that sample sizes smaller than about 1000 are not sufficient, but that sample sizes of 5000 are not necessary either (see Figure 1(b)). It also seems that the choice of the basis function in Kriging has a minor influence on the approximation quality of the meta model.

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