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Rare Event Prediction for Enhanced Control System Reliability of AWE Systems

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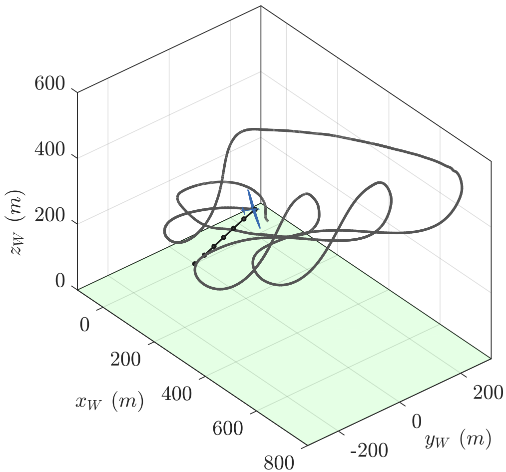
Reliable autonomous operation of Airborne Wind Energy (AWE) systems requires control algorithms that are able to attenuate the effect of stochastic disturbances on the control performance in continuously changing wind conditions. Assessing the stability and robustness of the control system is in general carried out using simplified system models where the real stochastic nature of the control problem is neglected. Therefore, a direct Monte Carlo approach is used in practice to increase the confidence in the control system's reliability. However, this approach performs poorly if it is used to estimate the effect and the probability of *rare events* such as strong gusts. Statistically, these events are located at the tails of the underlying joint probability density function. Consequently, only a few samples leading to rare events can be identified in a reasonable amount of time which leads to a biased probability estimate. In addition, it is difficult to recognize and leverage patterns if only a small set of samples is available that lead to a violation of a critical control requirement.

In this talk, we present an approach to predict rare events in the context of AWE using a combination of *Subset Simulations* (SS) [1] and time series classification. SS will be used to systematically create samples that lead to the violation of a specified closed loop performance criteria. Furthermore, based on the identified samples a time series classifier is trained that is able to detect critical situations using on-board sensor measurements before the AWE system enters an unrecoverable state. The approach will be evaluated by means of simulations of a generic AWE system operated in pumping cycle mode in randomly generated wind fields.



Pumping cycle flight path.

References:

[1] Au SK, Beck JL: Estimation of small failure probabilities in high dimensions by Subset Simulation. Probabilistic Engineering Mechanics (2001).