Master's thesis proposal

Sequential directional importance sampling method for structural reliability analysis

Background

Structural reliability analysis aims at estimating the failure probability of engineering systems with uncertain parameters modeled probabilistically. Among existing methods, sampling methods, based on Monte Carlo simulation (MCS), are generally preferred for reliability analysis of complex engineering systems due to their robustness. In this project, we will investigate sequential directional importance sampling (SDIS) [1] method. SDIS has proven to be efficient for reliability analysis of problems with small failure probability, multiple failure domains, and many input variables. However, its performance depends on the efficiency of the root-finding algorithm as well as the several user-specified parameters. Therefore, in this project, we will improve the performance of SDIS by tuning its parameters adaptively, and implementing of Kriging model combined with active learning strategy for searching the roots along every important direction. The method will be compared with the existing sampling methods, e.g., subset simulation [2], with several analytical benchmarks.

We expect that the student has successfully completed the course Estimation of rare events and failure probabilities (or a similar course) and is familiar with advanced sampling techniques and Kriging model. Good mathematical and programming skills will certainly prove helpful in this project

Objectives
The student conducting the proposed MSc thesis will learn:
- How to perform reliability analysis with state-of-the-art sampling methods.
- How to implement Kriging model for fitting "black-box" model adaptively.

Methodology
The suggested work flow is as follows:
- Develop in-depth understanding of the SDIS method and Kriging model, and implement them in Matlab.
- Develop an algorithm to apply Kriging model for searching roots.
- Develop an algorithm to tune the parameters of SDIS.
- Compare the performance of the method with existing methods.

Supervised by:
Kai Cheng (kai.cheng@tum.de), Engineering Risk Analysis Group, TU Munich

Starting date: as soon as possible

References

[1]   Cheng, Kai, Papaioannou, I, et al.: Rare event estimation with sequential directional importance sampling. Structural Safety 100: 102291, 2023.

[2]   Au, S.-K. and Beck, J. L.: Estimation of small failure probabilities in high dimensions by Subset Simulation. Probabilistic Engineering Mechanics, 16(4):263–277, 2001.

Technische Universität München

Ingenieursfakultät Bau Geo Umwelt
Engineering Risk Analysis Group
Prof. Dr. Daniel Straub

—

—