Engineering Risk Analysis Group
Prof. Dr Daniel Straub

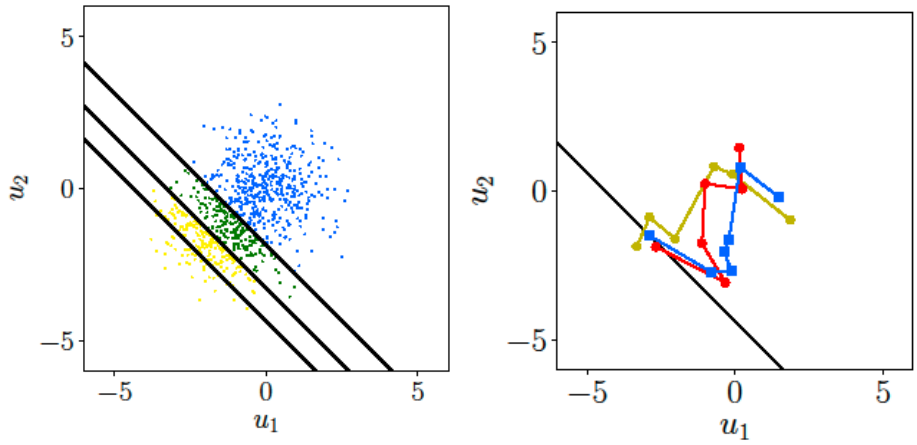
MSc thesis

Subset Simulation and Moving Particles methods for reliability estimation

Matthias Willer, October 2017

Background

Reliability analysis of structural systems deals with the estimation of the probability of rare events associated to failure. Different types of failure are represented by a so-called limit state function (LSF) which contains the model of the underlying physical system, and is typically described as a black-box. In order to estimate the probability of failure of the structural system, the uncertainty of the input parameters and system properties can be described in probabilistic terms. This allows us to use simulation-based approaches that provide statistical estimates of the failure probability. Monte Carlo simulation (MCS) is the most common method used to perform this task. However, despite being robust to the type and dimension of the problem, it becomes inefficient when the failure probability is very small ($< 10^{-5}$). In such cases, the use of advanced simulation approaches is required, as this is the case of Subset Simulation (SuS) and Moving Particles (MP).



SuS (left) and MP (right) move samples to the failure domain and estimate the failure probability based on the number of "steps". However, their theoretical background is quite different.

Methodology

In this thesis, the two MCMC-based reliability methods (SuS and MP) were implemented in a *Python*-based code. Further, a theoretical comparison was drawn and both algorithms were applied to a diverse type of reliability problems. Thus, we could also establish a practical comparison with respect to efficiency and accuracy.

Conclusion

We show that both methods lead to similar estimates for the failure probability requiring approximately the same computational resources. Moreover, we found that in terms of the generation of samples in the failure domain, the MP algorithm has an advantage over SuS. This is due to the fact that by construction the samples are nearly independent. The numerical examples also show that (due to the efficient generation of samples in the failure domain) the MP method can be efficiently applied in combination with surrogate models.

Supervised by M.Sc. Felipe Uribe
Prof. Dr. Daniel Straub