Bayesian analysis of rare events

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Abstract

In many areas of engineering and science there is an interest in predicting the probability of rare events, in particular in applications related to safety and security. Increasingly, such predictions are made through computer models of physical systems in an UQ framework. Additionally, with advances in IT, monitoring and sensor technology, more and more data on the performance of the systems is collected. This data can be used to reduce uncertainty, improve the probability estimates and consequently enhance the management of rare events and associated risks. Bayesian analysis is the ideal method to include the data into the probabilistic model. It ensures a consistent probabilistic treatment of uncertainty, which is central in the prediction of rare events, where extrapolation from the domain of observation is common. We present an efficient framework to performing Bayesian updating of rare event probabilities, termed BUS. It is based on a reinterpretation of the classical rejection-sampling approach to Bayesian analysis, combined with established methods for estimating probabilities of rare events. These methods include the First-Order Reliability Method (FORM), tailored importance sampling (IS) methods as well as Subset Simulation (SuS). In this contribution, we briefly review these methods in the context of the BUS framework and investigate their applicability to Bayesian analysis of rare events in different settings. We find that, for some applications, FORM can be highly efficient, enabling a Bayesian analysis of rare events with just a few model evaluations. Generally, BUS implemented through IS and SuS is more robust and flexible, and is still significantly more efficient than MCMC or other classical methods for Bayesian analysis.