The cross-entropy method for model-based prediction and updating of rare events

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Abstract

In many areas of science and engineering it is of interest to predict the probability of a rare event or failure event based on a computational model of an underlying system or process. This probability is defined through a potentially high dimensional probability integral, whereby the integration domain is only known point-wise in terms of the outcome of the model. The probability of failure is usually estimated with Monte Carlo-based sampling approaches, which treat the complex numerical models as a black box input-output relationship. The efficiency of crude Monte Carlo can be improved significantly by importance sampling (IS), provided that an effective IS density is chosen. The cross entropy (CE) method is an adaptive sampling approach that determines the IS density through minimizing the Kullback-Leibler divergence between the theoretically optimal IS density and a chosen parametric family of densities. This presentation discusses recent improvements of the classical CE method, which include (a) an alternative definition of the intermediate optimization problems that allows making better use of the samples at intermediate sampling levels and (b) a flexible parametric distribution family that is able to handle both low- and high-dimensional problems in Gaussian input spaces. We further discuss application of the CE method to Bayesian updating problems, whereby data on the system performance are used to improve predictions.

Keywords: reliability, importance sampling, cross entropy, Bayesian updating

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