Multilevel Monte Carlo covariance estimation: application to global sensitivity analysis in the context of open-channel flow simulations

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Abstract

Monte Carlo (MC) methods are popular and powerful approaches for the estimation of statistical parameters, such as expectations, variances and covariances of random variables. However, it is well known that the root mean square error of an MC estimator converges slowly as a function of the sample size.

Multilevel Monte Carlo (MLMC) methods were developed to improve the overall computational cost of MC sampling by introducing a sequence of so-called levels, usually corresponding to a hierarchy of numerical simulators with increasing accuracy and corresponding cost of individual simulations. Originally designed for the estimation of expectations, MLMC was recently extended to the estimation of higher-order statistical moments such as variances.

I will discuss the extension of MLMC to the estimation of covariances, which are particularly interesting for the computation of Sobol' indices in the context of sensitivity analysis. The resulting MLMC methodology is applied to the estimation of Sobol' indices in open-channel flow simulations using a numerical solver of the 1D shallow water equations. In this context, I will illustrate the numerical behaviour of the algorithm and demonstrate that significant cost reduction may be obtained.