Conditional Quasi-Monte Carlo with Active Subspaces

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Conditional Monte Carlo is a powerful strategy for enhancing the efficiency and accuracy of quasi-Monte Carlo and randomized quasi-Monte Carlo methods. By pre-integrating over a variable in a closed form, it reduces the variance and can potentially improve the smoothness of the integrand. Selecting the appropriate variable for pre-integration requires careful consideration of both the variance reduction factor and the feasibility of the pre-integration step. For integrals with respect to a Gaussian distribution, there is the flexibility to pre-integrate over any linear combination of variables. We introduce a systematic method for choosing the pre-integration direction, leveraging the active subspace decomposition to identify the most important direction. In some scenarios, pre-integration is feasible only along directions that satisfy certain constraints. Therefore, we propose to compute the active subspace decomposition subject to these constraints so that pre-integration can be easily carried out. The effectiveness of the proposed method is demonstrated through its application to derivative pricing problems under the Black-Scholes model and various stochastic volatility models.