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A Spline-Based Approach to Uncertainty Quantification with Applications to Density Estimation

Uncertainties and noise are prevalent in mathematical models in all branches of science. Because of the randomness, the calculation of the deterministic value of a quantity of interest is replaced by the calculation of its moments (e.g., mean and standard deviation) and, ideally, its Probability Density Function (PDF). Standard approaches to these tasks are either statistical, such as Kernel Density Estimators (KDE), and spectral methods such as the gPC. We present a novel spline-based, non-intrusive algorithm for uncertainty quantification. This method outperforms existing methods, which are often vastly inefficient for PDF estimation. Furthermore, although standard methods such as gPC approximate moments with spectral accuracy, the spline-based method approximates moments more accurately given small sample sizes. Thus, when each solution of the underlying model is computationally expensive, the spline-based model can be a more efficient choice for moment-approximation as well. The spline-based method can also approximate non-smooth quantities of interest, which is often prohibitive in spectral stochastic methods. We present application of our algorithm to nonlinear optics and computational fluid dynamics.