A Distributional Monte Carlo Method for the Boltzmann Equation

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Stochastic particle methods (SPM) for the Boltzmann equation have gained popularity in recent years for the prediction of flows where continuous equations for fluid dynamics are not valid. Among SPMs, the Direct Simulation Monte Carlo (DSMC) methods have been the standard computational method in the field of rarefied gas dynamics. The DSMC method employs a point measure approximation to the distribution function, as simulated particles may possess only a single velocity. This unphysical representation limits the method to converge only weakly to the solution of the Boltzmann equation.

In this talk, we introduce a Distributional Monte Carlo (DMC) method which provides for simulated particles to possess velocity distribution functions, rather than singular velocity vectors. Additionally, we discuss two specific implementations of the technique. The first approach applied kernel density estimation to DSMC. While no variance reduction was observed, the approach was shown to exhibit stronger convergence for the space homogeneous Boltzmann equation. The second implementation represented a hybrid stochastic/deterministic scheme employing the BGK equation for deterministic computation of collision outcomes. When applied to the Bobylev problem, the DMC-BGK method demonstrated a variance reduction of four orders of magnitude over the Nanbu-DSMC method.