Approaches for Emulating the Boltzmann Equation When Particle Simulation Becomes Inefficient

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Particle simulation is a widely used approach for emulating the physics of the Boltzmann equation in nonequilibrium gas and plasma flows. The direct simulation Monte Carlo (DSMC) and Particle-In-Cell (PIC) methods are particularly popular for engineering analysis. While offering positive qualities such as being able to handle geometric complexity and the availability of many physical models, particle simulation methods may also become very inefficient. Examples of such inefficiency include spending a dominant amount of computation time in regions of a flow that are close to equilibrium, and an inability to resolve important low-probability physics such as energetic tails of distribution functions. In this talk, two approaches are discussed for addressing these limitations of particle methods: (1) a hybrid particle-continuum method for efficient processing of near-continuum regions of a flow field, and (2) deterministic computation of particle distribution functions to resolve low-probability physics. The approaches are illustrated using their application to a high-speed gas flow and a plasma propulsion system.