Spring 2016

Mathematical Sciences Colloquium

"Sparse and multilevel methods for particle-in-cell simulations in plasma physics"

The "particle-in-cell" (PIC) method is a technique for solving kinetic PDEs that has been a standard simulation tool in plasma physics for 50 years. Originally, the method was an attempt to circumvent the curse of dimensionality when solving high-dimensional kinetic PDEs by combining particle- and grid-based representations. The technique has been enormously successful in many regards but even today, generating a quantitatively accurate solution in complex, three-dimensional geometry requires many hours on a massively parallel machine.

Two prominent reasons for the massive complexity of PIC schemes are the statistical noise introduced by the particle representation and the fact that multiple disparate physical time-scales necessitate taking enormous numbers of time-steps. We present approaches to circumventing each of these difficulties. First, we propose the use of 'sparse grids' (see e.g. Griebel et al, 1990) to estimate grid-based quantities from particle information. We show that this can dramatically reduce statistical errors while only increasing grid-based error by a logarithmic factor. Second, we present a multilevel - in time - technique in the spirit of the multilevel Monte Carlo (MLMC) method (see e.g. Giles, 2008). The idea is to combine information from simulations using many particles and a large time step on the one hand with simulations using few particles and a small time step on the other. This is done in such a way as to generate a new solution that mimics one with many particles and a small time-step, but at dramatically reduced cost. Scalings of the computational complexity of PIC codes using each of these approaches will be discussed, and proof-of-principle results will be presented from solving the 4-D Vlasov-Poisson PDE. Finally, we will discuss the prospects for combining the two approaches, parallel issues, and other future directions.

Speaker: Lee Ricketson

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Thursday, May 5, 2016

(Joint with RTG/SIAM)

Time: 4:00 – 5:00 PM

Location: Lally 102

Rensselaer

Host: John Jacangelo