LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-414506

Boyd Report1

A. Crow

July 8, 2009

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Lawrence Livermore National Labs

Release Number:	LLNL-TR-414506
Title:	Boyd report1
Author:	Andrew Joseph Crow
Date:	8/July/2009

Andrew Crow:

Year End report.

A. Crow arrived at Lawrence Livermore national laboratory with the intention of continuing work on the Complex Particle Kinetic (CPK) method developed by D. Larson and D. Hewett.[1] [2] A. Crow had previously worked on duplicating the results of D. Hewett in his previous work. Since arrival, A. Crow has been working with D. Larson on a slightly different project. The current method, still under development, is a Particle in Cell (PIC) code with the following features:

1) All particles begin each timestep at a gridpoint.
2) Particles are then advanced in time using a standard special advancement method. The exact method has not been decided upon, but there are many reliable methods from which to choose. [3][4].
3) All particles within each cell undergo a simultaneous implicit collision step. This is the current area of focus. Currently, A. Crow is not aware of any method of performing implicit collisions over a large number of charged particles. Implicit methods for charged particle movement and electron-electron collisions, have been developed.[3][5] The work of L. Pareschi and G. Russo on the Time Relaxed Direct Simulation Monte Carlo method, also appears to be a good basis for implicit particle collisions.[6]
4) Each individual particle will be divided into a set of particles with a Gaussian velocity distribution. This will collect some of the thermal effects created by the collisions. This algorithm has not been created.
5) Particles will be projected on to the grid points. Currently, a linear weighting technique is intended to be used, but has not settled upon.
6) Once on the gridpoints the particle number will be reduced using a set of quadrature points based on the third order velocity moments of the particles. The method proposed by R. Fox has been programmed and shown to conserve energy, momentum and mass to machine precision.[7] In addition to reducing the number of particles this method will work to quiet the simulation it will behave as a higher order version of the Quiet DSMC method proposed by B. Albright et al.[8]
7) These quadrature points then become the new particles for the next timestep.

The advantage of this method can be many: The self force on ions can be easily removed since all particles begin on grid points. The size of the timesteps should not be limited by collision rate, and should only be impacted by particle travel time through the cell. The particle reduction technique should keep many of the higher order features of the particle distribution while reducing the number of particles in the system. It should also quite the variance in the system.

The two largest unknowns, at this time are, how large a part numerical diffusion will play in the scheme and how computationally expensive each timestep will be.

A. Crow

References

[1] D.W. Hewett, "Fragmentation, merging, and internal dynamics for PIC simulation with finite size particles," accepted by *J. Comp. Phys.* (2003)

[2] D. J. Larson, "A Coulomb Collision Model for PIC Plasma Simulation," *J. Comp. Phys.* **188**, 123 (2003)

[3] A. B. Langdon and B I Cohen and A Friedman, "Direct Implicit Large Time-Step Particle simulation of Plasma," Journal of Computational Physics, 51, 107-138 (1983)

[4] C K Birdsall and A B Langdon, "Plasma Physics via Computer Simulation, McGraw-Hill Book Company," New York, 1985

[5] R.J. Kingham and A.R. Bell "An implicit Vlasov–Fokker–Planck code to model non-local electron transport in 2-D with magnetic fields," Journal of Computational Physics, 194, (2004), 1–34

[6] L Parechi and G Russo, "Time Relaxed Monte Carlo Methods for The Bolzmann Equation," SIAM, Journal of Scienticif Computing, Vol 23, No 4, 1253-1273

[7] R. O. Fox, "A Quadrature-based third-order moment method for dilute gas-particle flows," Journal of Computational Physics, 227 (2008) 6313-6350

[8] B. J. Albright and W. Daughton and D.S. Lemons and D. Winski and M. E. Jones "Quiet direct simulation of Plasmas," Physics of Plasmas, vol 9, no 5, (2002) 1898-1904.