Los Alamos NATIONAL LABORATORY EST.1943

Momentum Deposition in Curvilinear Coordinates

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The momentum imparted into a material by thermal radiation deposition is an important physical process in astrophysics and inertial confinement fusion (ICF) simulations. In recent work [2] we presented a new method of evaluating momentum deposition that relies on the combination of a time-averaged approximation and a numerical integration scheme. This approach robustly and efficiently evaluates the momentum deposition in spherical geometry. Future work will look to extend this approach to 2D cylindrical geometries.

Background and Motivation

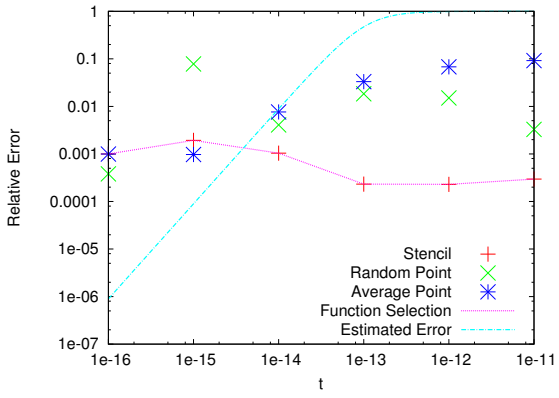
The Jayenne software development team has recently implemented a 1D Spherical mesh capability to replace the pre-existing simplified 3D Cartesian pyramid mesh approximation [1]. This change improved 1D simulation accuracy while slight reducing simulation run times. In 1D spherical geometry particles are tracked in curved trajectories complicating the momentum deposition evaluation.

Momentum deposition in spherical coordinates cannot be evaluated analytically in combination with continuous energy deposition models, as was done in Cartesian coordinates [3, 4]. In our recent work [2], we compared a new functional absorbed-momentum deposition approach for spherical coordinates that is a combination of a simple time-averaged approximation and a numerical integration stencil, to three other common absorbed-momentum deposition methods.

Description/Impact

The new functional approach explicitly determines which Monte Carlo paths can be accumulated using the simple (and fast) time averaged momentum deposition, and those that require the more accurate (and expensive) numerical integration scheme. This is done using the approximate magnitude of the leading order error in the time average momentum deposition scheme.

We compared the new functional absorbed-momentum deposition approach to three other common absorbed-momentum deposition methods: random point, time-averaged, and numerical integration. Each methods was used to compute the momentum deposition from a point source located in a homogeneous infinite sphere. The new functional method proved to be the least sensitive of all the methods tested to the 4 independent variables: number of particles, size of the time step, material optical thickness, and source location. The figure below shows that the new functional approach robustly preservers an accurate momentum deposition calculation regardless of the time step size. The improved accuracy, and robustness, of the functional method is gained with very little extra computational cost.



Relative error versus a varied time step size t

Anticipated Impact

Users will notice a significant improvement in Jayenne 1D spherical geometry simulations compared to previous simulation that used the approximate 3D Cartesian geometry. This will include a 10-20% decrease in simulation run times and improved fidelity of the momentum deposition calculation.

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Path Forward

The Jayenne development team will continue to pursue methods to increase simulation fidelity and efficiency. This will include investigating the use of cylindrical coordinates to replace a 3D Cartesian wedge approximation. This cylindrical geometry development will leverage much of the work highlighted here for 1D spherical geometry.

Acknowledgements

Los Alamos Report LA-UR-LA-UR-15-26124. Funded by the Department of Energy at Los Alamos National Laboratory under contract DE-AC52-06NA25396.

References

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