Remapping and Advection Considerations in FLAG

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ABSTRACT

Events such as the activation of a physics package or a change in mesh strategy may benefit from massive mesh relaxation. Two methods to massively relax mesh exist in the FLAG hydrocode—advection subcycling and mesh remapping. In an advection subcycle, the proposed relaxation of each point is scaled uniformly based on an advection volume limit. Advection subcycling may require hundreds or thousands of subcycles to massively relax the mesh. Variables are advected with second-order accuracy, causing each subcycle to incur advection error if fields are nonlinear. In contrast, mesh remapping calculates exact intersections between the original and massively relaxed mesh, then performs a single second-order conservative remap. Both methods use identical relaxers and preserve the topology of the original mesh. An identical set of variables is updated in both methods.

This work compares the accuracy of advection subcycling and mesh remapping. Simple test problems including 1) linear fields, 2) nonlinear fields, and 3) slip surfaces are used to investigate each method.

The first test examines linear fields on unit square meshes that are initially distorted. Initial meshes are biased in the x, and both x and y directions. A third initial mesh is biased in both the x and y directions, with a random perturbation. The final mesh is uniformly relaxed. Several linear fields are remapped using both methods. In all tests, density (mass) is the field of interest, although both methods are generalized for any conserved quantity. Both advection subcycling and mesh remapping were found to be exact for linear fields.

The second test investigates nonlinear fields. The mesh is initially biased in both x and y directions, and randomly perturbed for various resolutions. Again, the final mesh is uniformly relaxed. Both methods converge with approximate second-order accuracy. For all simulations, mesh remapping has lower L1 relative error. The difference in L1 error between advection subcycling and mesh remapping is $\sim$10x for a hyperbolic tangent field, which approximates a discontinuity.

The third test simulates the alignment of a slip surface. Adjacent slip surfaces can be cleanly stitched together if both surfaces are aligned before their removal. However, both advection subcycling and mesh remapping incur faceting error as the discretized boundary is relaxed. Faceting error causes unphysical field defects along curved boundaries which can disrupt simulations and preclude the clean removal of slip surfaces. This test consists of a unit density field on a mesh with a non-uniform curved boundary. The final mesh is uniformly relaxed along the curved boundary. Both methods demonstrated field perturbations due to faceting error, although the severity is less with mesh remapping. As implemented in FLAG, mesh remapping can by followed by a process that repairs faceting error along slip surfaces. This is accomplished by scaling conserved quantities on a per-zone basis by the post-remap_zone_volume/intersection_volume. Conservation is enforced by applying a uniform factor to conserved quantities in zones adjacent to the slip surface. In testing, this correction is able to faithfully represent the original conserved field.

Tests of nonlinear fields indicate mesh remapping is more accurate, and with a correction, may reduce the effect of faceting error along slip surfaces. Motivated by the differences found in these simple tests, advection subcycling and mesh remapping will be compared in integrated simulations. The results will inform best practices for user simulations.