VOLUME TRACKING ON ADAPTIVELY-REFINED STRUCTURED MESHES

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We consider the implementation of a piecewise-linear interface calculation (PLIC) volume tracking method on an adaptively-refined structured mesh. The motivation is to accurately simulate the behaviour of interfacial flow phenomena when the length scales and local curvatures of the interfaces vary significantly. For example, consider the splash of a droplet as it impacts a solid or liquid surface. The diameter of the initial droplet is one or two orders of magnitude greater than the diameter of the satellite droplets that form. Previous three-dimensional simulations of such phenomena (e.g. [1,2]) utilized volume tracking methodologies on fixed square meshes. The resulting calculations poorly resolved the satellite droplets, and so achieved little more than to demonstrate the possibility of such calculations.

To utilize simulation as an investigative tool applied to such phenomena, simulations must employ adaptive refinement to resolve the multiscale features of the flow in some uniform way. There are a few examples of volume tracking implementations that uniformly resolve interfaces at finer resolutions than the underlying velocity and pressure fields (e.g. [3]). But what is required is a simulation capability that resolves, for example, the satellite droplet as accurately as the original droplet.

Leading to the long term objective of an adaptive incompressible interfacial flow code, we present details of the implementation of a two-dimensional PLIC algorithm (similar to that of Youngs [4]) onto an adaptively-refined mesh structure, where the criterion for refinement is related to the local curvature of an interface. The implementation is non-trivial for several reasons. The calculation of interface orientation is complicated by the presence of non-uniform stencils about a cell-center. Mesh refinement requires that coarse volume fractions be refined, which is an iterative process constrained by conservation of volume. And ideally, the volume tracking calculation is refined in time as well as space (like the AMR approach of Berger and Colella [5]), such that volume tracking occurs at similar Courant numbers over the entire domain. We conclude with a presentation of validation results of the scheme, and compare results and computational costs to corresponding simulations on fixed meshes.

References

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