Nested Dissection Interface Reconstruction in Pececillo

Z. Jibben, zjibben@lanl.gov
N. Carlson, nnc@lanl.gov
M. Francois, mmfran@lanl.gov

A nested dissection method for interface reconstruction in a volume tracking framework has been implemented in Pececillo, a mini-app for Truchas, which is the ASC code for casting and additive manufacturing. This method provides a significant improvement over the traditional onion-skin method, which does not appropriately handle T-shaped multimaterial intersections and dynamic contact lines present in additive manufacturing simulations. The resulting implementation lays the groundwork for further research in contact angle estimates and surface tension calculations.

Background and Motivation

Pececillo is a mini-app that represents the casting and additive manufacturing processes found in the production code Truchas. It is being used to investigate improved algorithm and code designs for current and future architectures prior to their deployment in Truchas.

The traditional onion-skin method [4] currently implemented in Truchas reconstructs the phase interface between multiple immiscible media modeled with the volume of fluid method by summing volume fractions in material order to calculate normal vectors, which are used to calculate the interface position across the cell. For T-junctions this leads to the unphysical situation where reconstructed interfaces overlap, creating a zone occupied by multiple materials.

Description

The nested dissection method [2] addresses this issue by instead sequentially removing zones behind a reconstructed phase-interface from the computational cell, and locating later interfaces on the remaining polyhedron. This produces a collection of polyhedra which describe the material geometry in a cell which can then be used for calculating material fluxes.

The interface normal vector is estimated from the normalized gradient of the volume fraction,

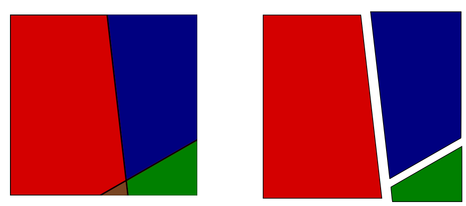
$$\hat{\mathbf{n}}_{m,i} = \frac{\nabla \mathcal{F}_{m,i}}{|\nabla \mathcal{F}_{m,i}|}. \quad (1)$$

The phase interface location is then found using Brent's iterative method to solve for the plane constant ρ in

$$V(\hat{\mathbf{n}}_{m,i}, \rho) - \mathcal{F}_{m,i} V_i = 0 \quad (2)$$

where V_i is the cell volume and $V(\hat{\mathbf{n}}_{m,i}, \rho)$ is the volume of the region of the polyhedron clipped by the phase interface [3] described by the equation of a plane

$$\mathbf{x} \cdot \hat{\mathbf{n}}_{m,i} - \rho = 0. \quad (3)$$



Onion Skin (left), Nested Dissection (right)

Anticipated Impact

The nested dissection method is expected to greatly increase the accuracy of dynamic contact line tracking, and lays the groundwork necessary for research in prescribing dynamic contact angles. The resulting code will be adapted for implementation in Truchas, improving its additive manufacturing simulation capability.

Path Forward

Scalable methods for calculating surface tension and contact angles are now being investigated in Pececillo using the improved interface reconstruction now available. Other interface reconstruction improvements, such as a direct analytic approach [1] and a material-order-independent method [5], present considerable advantages and may also be implemented.

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