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IMPROVING MASS CONSERVATION IN A STABILIZED LEVEL-SET APPROACH FOR HIGH-DENSITY-RATIO FLOWS

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Interfacial flows of two fluids with a high density-ratio, such as air and water, provide significant computational challenges, particularly when the interface is captured with a level-set based finite element method. When gravity is the dominant force, even a quiescent air-water interface can experience significant mass loss due to quadrature errors across the interface. While balanced-force methods exist for discretely balancing the capillary force and pressure gradient, nothing yet exists for handling the discontinuous pressure gradient that arises from the density discontinuity. These questions become even more important when the fluid densities are not constant in time. In this talk, we present several improvements to the standard level-set approach that significantly improves mass conservation in interfacial flows involving variable-density fluids.

For solenoidal flows, the standard $\nabla \cdot u = 0$ formulation for the continuity equation is sufficient, even for high density ratios. Variable-density, non-solenoidal flows, however, require an expanded mass conservation equation, which can lead to quadrature errors across the interface leading to significant mass loss. We show that dividing the continuity equation by the fluid density improves the weighting across the interface, greatly improving mass conservation. Secondly, a balanced-force-like approach is developed for discretely balancing the gravitational acceleration with the pressure gradient and inertial terms in the momentum equation. Various options will be discussed, including projecting the gravitational acceleration into a scalar potential, along with other projection ideas.

These improved techniques will first be demonstrated on a quiescent stratified liquid system. Quadrature errors in the continuity equation will be directly compared, along with mesh convergence of the methods. The impact on transient problems will be demonstrated through a gas bubble rising through a liquid. Finally, the technique will be demonstrated with a variable-density model for foam curing inside a complex mold.

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