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Phase Conservative, Monolithic Level-Set Method

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In fluid mechanics the interaction of fluids with distinguishable material properties (e.g. water and air) is referred as multiphase flow. In this work we concentrate on the representation and time evolution of the interface. There is an extensive list of methods to treat material interfaces. Popular choices include the volume of fluid and level-set methods.

We propose a novel level-set like methodology for multiphase flow that preserves the initial mass of each phase. The model combines ideas from the volume of fluid and level-set methods by solving a non-linear conservation law for a regularized Heaviside of the (distance function) level-set. This guarantees conservation of the volume enclosed by the zero level-set. The equation is regularized by a consistent term that produces a non-singular Jacobian and penalizes deviations from the distance function. The result is a non-linear monolithic model for a phase conservative level-set where the level-set is given by the distance function. The continuous model is monolithic; meaning that only one equation is needed, doesn't require numerical artifacts such as: numerical stabilization, post re-distancing, artificial compression, flux limiting and others, all of which are commonly used in either level-set or volume of fluid methods. In addition, we have only one parameter that controls the strength of regularization/penalization in the model.

We start the presentation reviewing the main ingredients of this model: 1) a conservative level-set method by [2], which combines a distanced, non-conservative level-set method with the volume of fluid method via a non-linear correction and 2) elliptic re-distancing by [1]. Afterwards, we motivate our formulation, present a first model which we then modify to resolve some difficulties and, finally, present a full discretization given by continuous Galerkin Finite Elements in space and a second-order Implicit-Explicit time integration.

We demonstrate the behavior of this model by solving different benchmark problems in the literature of level-set methods.

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