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A Robust, Fully Adaptive Hybrid Method for Two-Phase Flows

*** Hector D. Ceniceros[1], Alexandre M. Roma[2], Aristeu da Silveira-Neto[3], and Millena M. Villar[4]**

[1] Depart. of Mathematics
University of California
Santa Barbara, CA 93106, USA
hdc@math.ucsb.edu
www.math.ucsb.edu/~hdc

[2] Departamento
de Matemática Aplicada
Universidade de São Paulo
Caixa Postal 66281
CEP 05311-970
São Paulo-SP, Brasil.
roma@ime.usp.br
www.ime.usp.br/~roma

[3],[4] Faculdade de Engenharia Mecânica,
Universidade Federal de Uberlândia 38400-902
Campus Santa Mônica
Uberlândia, MG, Brasil
[3]aristeus@mecanica.ufu.br
[4]mmvillar@mecanica.ufu.br
www.ltcm.mecanica.ufu.br

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ABSTRACT

Two-phase flows are the source of multiple applications. Moreover, several fundamental hydrodynamic instabilities and interactions take place in these flows. In immiscible, incompressible two-phase flows, fluid interfaces separate masses of fluid with constant but different material properties in each bulk phase. The molecular mismatch of the two components gives rise to surface tension and this interfacial force plays a fundamental role in nearly all multi-phase flows of physical interest. Moreover, multi-phase flows are typically multi-scale; the important phenomena of flow-induced drop interaction and the production of short wavelength capillary waves on spilling breakers illustrate common two-phase systems that exhibit the presence of multiple time and length scales. Therefore, the effective numerical simulation of these flows requires both an accurate representation of the singularly supported interfacial forces and of all the physically relevant flow quantities and to faithfully capture the disparate scales. Here, we present a method that responds to these requirements with computational efficiency and robustness.

The proposed method originates from the hybrid level-set/front-tracking (LeFT) setting proposed in [1], from the fast and accurate fluid indicator developed in [2], and from the adaptive immersed boundary (IB) method first introduced by Roma, Peskin, and Berger [3] . LeFT does an explicit tracking of the interface using the IB method framework and employs a continuous level-set function as a fluid indicator. The interfacial tension and the geometric quantities are evaluated from the tracked interface while the the level set function is used to update the material quantities. Thus, the method retains one of the advantages of front-tracking (accurate evaluation of interfacial quantities) and at the same time benefits from a continuous, geometry-based fluid indicator, the level-set function. Moreover, this signed distance function is updated only locally, in a thin neighborhood of the interface, at optimal computational cost and is computed to machine precision for a piece-wise linear representation of the interface [2]. Here, we also use a hybrid Lagrangian/Eulerian approach due to Shin, Abdel-Khalik,

Daru, and Juric [4] to evaluate the tension force. This hybrid force formulation combined with the accurate fluid indicator leads to an unprecedented reduction of spurious currents.

One of the central objectives of this work is to present a robust, fully adaptive LeFT method to resolve accurately and efficiently interfacial forces and the disparate scales that are typical of many challenging but important two-phase flows. We achieve this by endowing the LeFT approach with adaptive mesh refinements (AMR), an efficient and robust time discretization, and a dynamic control of the distribution of the Lagrangian nodes in the interfacial grid. As a bonus, with the increased resolution afforded by the AMR, we are able obtain an accurate area conservation for long time integrations.

REFERENCES

[1] H. D. Ceniceros, ”The effect of surfactants on the formation and evolution of capillary waves”, *Phys. Fluids*, Vol. **15** (1),245–256, 2003.

[2] H. D. Ceniceros, A. M. Roma, ”A multi-phase flow method with a fast, geometry-based fluid indicator”, *J. Comput. Phys.*, Vol. **205**, 391–400, 2005.

[3] A. M. Roma, C. S. Peskin, M. J. Berger, ”An adaptive version of the immersed boundary method”, *J. Comput. Phys.*, Vol. **153**, 509–534, 1999.

[4] S. Shin, S. Abdel-Khalik, V. Daru, D. Juric, ”Accurate representation of surface tension using the level contour reconstruction method”, *J. Comput. Phys.*, Vol **203**, 493–516, 2005.