Lagrange-Euler Lattice-Boltzmann Method and its application to two-fluid flows dynamics with possibly high density ratio

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Two-fluid extensions of Lattice Boltzmann methods with free boundaries usually consider "microscopic" pseudopotential interface models. In this paper, we rather propose an interface-capturing Lattice Boltzmann approach where the mass fraction variable is considered as an unknown and is advected. Several works have reported the difficulties of LBM methods to deal with such two-fluid systems especially for high-density ratio configurations. This is due to the mixing nature of LBM, as with Flux vector splitting approaches for Finite Volume methods. We here give another explanation of the lack of numerical diffusion of Lattice Boltzmann approaches to accurately capture contact discontinuities. To fix the problem, we propose an arbitrary Lagrangian-Eulerian (ALE) formulation of Lattice-Boltzmann methods. In the Lagrangian limit, it allows for a proper separated treatment of pressure waves and advection phenomenon. After the ALE solution, a remapping (advection) procedure is necessary to project the variables onto the Eulerian Lattice-Boltzmann grid.

We explain how to derive this remapping procedure in order to get second-order accuracy and achieve sharp stable oscillation-free interfaces. It that be shown that mass fractions variables satisfy a local discrete maximum principle and thus stay in the range $[0, 1]$. The theory is supported by numerical computations of rising bubbles (without taking into account surface tension at this current state of development).

Even if our methods are currently used for inviscid flows (Euler equations) by projecting the discrete distributions onto equilibrium ones at each time step, we believe that it is possible to extend the framework formulation for multifluid viscous problems. This will be at the aim of a next work.

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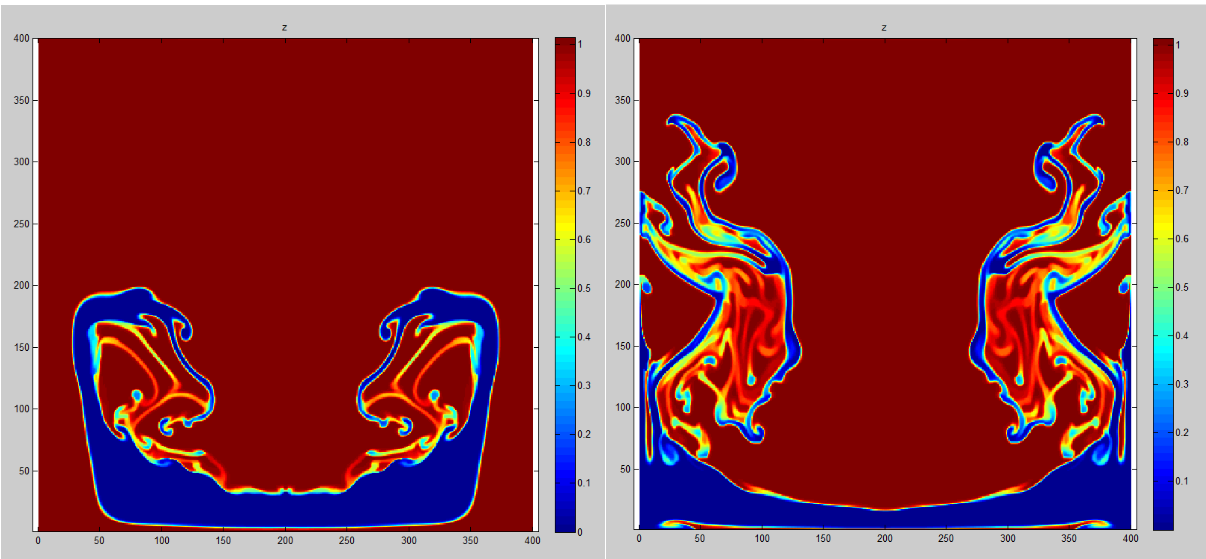

Figure 1: Free fall of an initial square block of a dense fluid surrounded by a lighter fluid into a box

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