Implicit Boundary and anisotropic mesh adaptation for multi-phase flows

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ABSTRACT

Multi-phase flow calculations can be performed by solving directly the heterogeneous Navier Stokes equations. The interfaces between phases: liquids gas or solids can be represented explicitly by a part of the mesh that means body fitted approaches or implicitly as the zero value of a scalar field as in the level set methods. In this paper we are following an implicit boundary strategy [1] controlled by an anisotropic mesh adaptation technique. Anisotropic meshing is driven by a metric field calculated from an edge based error estimate following the theory given in [2] and [3]. It enables to recover an accurate boundary representation and to fulfill a stability requirement of the multiphase flow solver due to the thickness of the interface inherent of these approaches and the local mesh size.

Indeed, multiphase flow (including free boundary problem) means to manage discontinuities at the interfaces, while the adaption framework theory needs regularity of the background solution. The proposed technique relies on a regularization approach of the multiphase modelling. The regularization is derived from a smooth Heaviside function constructed from the hyperbolic tangent of the level set, the regularization parameter being typically, a thickness of the interface. The thickness is normally related to the mesh size, but it is shown that adaptive meshing enables to reverse this condition: fixing the thickness parameter and accounting for the adaptation process to fulfill the mesh size condition. The sharpness of the interface will depend only on the thickness parameter. It will be shown that by adapting the mesh both on all the component of the velocity [4] and the smoothed Heaviside function enables to attain a very sharp interface even in almost turbulent multiphase flow.

Finally, it appears that this approach does not need any other treatment at the interface since the apparent jump (pressure gradient, velocity) that otherwise pollute the solution are well and smoothly captured. Moreover it combines well with the convected Level Set method [5] for large deformation of interface.

Several examples will be discussed with applications in fluid structure interaction [6], moving free surface and moving multiphase including surface tension at high Reynolds flows.

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