Adaptive anisotropic meshing and implicit boundary for general multiphase computation

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ABSTRACT

Complex geometries can be embedded in a mesh by using an implicit boundary representation as in the level set method or any equivalent scalar field. Such approaches enable a much more flexible way for building complex multi-domain simulations than classical body-fitted techniques that required to constraint boundaries and interfaces into the volume mesh. However, the geometrical accuracy of implicit representations depends on the fineness of mesh. In fact, the implicit function used to define the geometry must be interpolated onto the mesh and a lack of geometrical accuracy is only due to the interpolation error of the exact solution. Therefore, we propose to use the anisotropic mesh adaptation machinery, based on the interpolation error estimate, to improve the implicit boundary approach, showing that it can compete with body fitted technique in accuracy[1]. However, numerical methods able to deal with implicit boundary and anisotropic meshing technique must be well designed. Here, we deal with stabilized Finite Element solvers that have been shown to be very effective at high Reynolds Number and able to deal with unstructured anisotropic meshes containing highly stretched elements [2].

Moreover, we rely on a multiphase flow solver approach in order to deal with the discontinuity between fluids and solid domains. Multiphase flow calculations are based on a heterogeneous Navier Stokes solver coupled to the implicit function solver acting as a phase descriptor, (an instance of a distance function for known geometry or the convected level set method [3] for deformable surface). The last ingredient is the regularization of the Heaviside function depending on a thickness that controls the sharpness of the interface. Adapting the mesh both on all the component of the velocity and the Heaviside function enables very sharp interfaces even in almost turbulent multiphase flow.

The mesh technology is based on a local mesh topology modification kernel and anisotropy by using the metric field construction proposed in [4] and extended in [5]. Several examples will be proposed in the context of complex fluid solid flow, fluids with surface tension and turbulent multiphase flows in industrial applications.

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