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Mesh Adaptation Applied to Unsteady Simulation of Bi-Fluid Flow with Level Set

*** Damien Guégan[1,3], Frédéric Alauzet[2], Olivier Allain[3] and Alain Dervieux[1]**

[1] INRIA, projet Smash
2004 route des Lucioles,
Sophia-Antipolis, 06902, France
damien.guegan@lemma-ing.com

[2] INRIA, projet Gamma
Domaine de Voluceau - Rocquencourt
B.P.105, 78135 Le Chesnay, France
frederic.alauzet@inria.fr

[3] LEMMA
938 avenue de la République
La Roquette-sur-Siagne, 06550,
France
olivier.allain@lemma-ing.com

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ABSTRACT

The simulation of bi-fluid flow is a difficult numerical problem due to the large discontinuity of physical properties (density, viscosity) and variables gradients (velocity, pressure). Among the variety of tracking interfaces methods, the level set method coupled with mesh adaptation techniques permits to advect with higher accuracy the interface, reducing the error in the resolution of the discontinuity.

We use a mixed-element-volume method with a projection method in the standard P1 finite-element framework for the resolution of bi-fluid incompressible Navier-Stokes equations. The interface is represented by the zero level contour of a distance function level set. We solve the advection of the level set fonction (ϕ) with the following algorithm:

i) advection of ϕ^n with second-order MUSCL scheme $\Longrightarrow \overline{\phi}^{n+1}$

ii) redistancing of $\overline{\phi}^{n+1} \Longrightarrow \tilde{\phi}^{n+1}$

iii) modification of $\tilde{\phi}^{n+1}$ to enjoy a conservation property $\Longrightarrow \phi^{n+1}$.

We combine this method with the following recent techniques of mesh adaptation:

- multi-scale anisotropic mesh adaptation, to have an optimal control of the interpolation error, applied to the moment to accurately compute the fluid dynamic [1]
- anisotropic mesh adaptation specifically dedicated to the level set to displace precisely the interface. With this approach the geometric properties of the interface (curvatures) are taken into account by the specified metric.
- an unsteady mesh adaptation algorithm coupled with metrics intersection in time in order to control the time accuracy of the unsteady simulation during the mesh adaptation process [2].

We first propose a mesh convergence study to evaluate the method on the simple case of a circle in rotation. We compare this order with a theoretical limit derived from the mesh adaptation theory [1].

Then, two-dimensional and three-dimensional realistic examples are proposed to illustrate the efficiency of the proposed approach. These examples are falling water column impacting an obstacle [3], see Figure 1, and an unsteady free surface wave arround a NACA 0024 foil [4]. In each case, obtained results show good agreement with experimental data.

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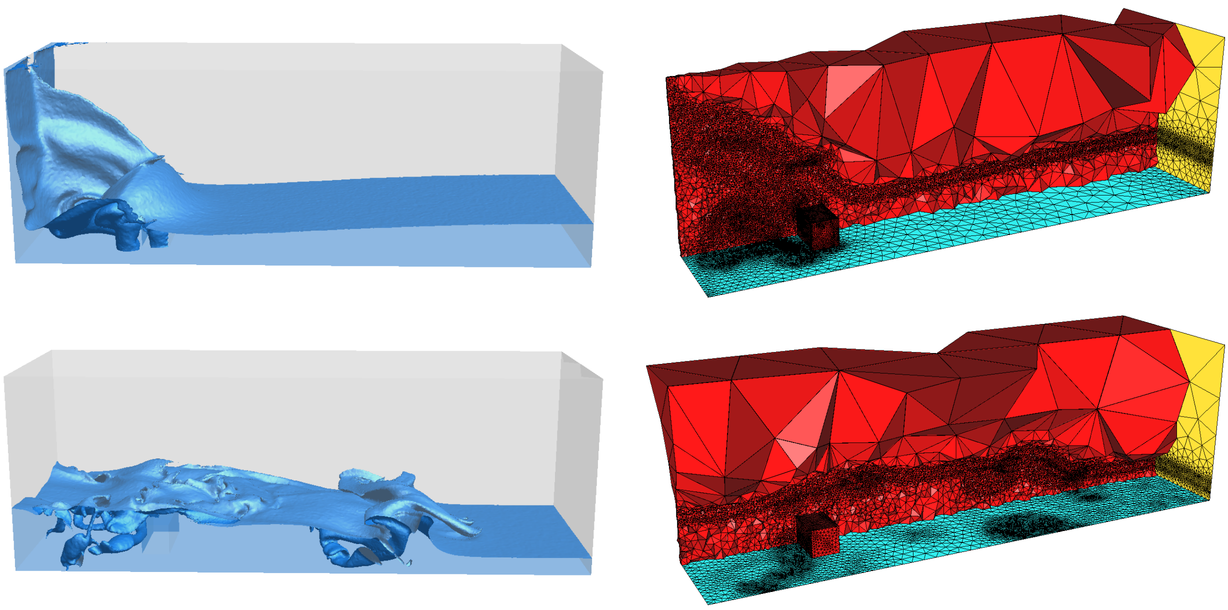

Figure 1: 3D falling water column on an obstacle at $T = 1.2$s (top) and $T = 2.4$s (bottom). Left, the interface and right, the corresponding adapted meshes.