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A SURFACE TENSION METHOD FOR VOF USING A MARCHING-CUBE ISOSURFACE CONSTRUCTION ALGORITHM

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In the pursuit of an integrated framework for simulating phenomena of fluid dynamics in smaller length scales, the accurate modelling of Surface Tension (ST) is of major importance. Specifically, in cases where the surface separating the two fluids (the interface) undergoes complex topological changes, ST plays a key role in capturing the local flow characteristics and the interface's geometry. The purpose of this work is to present a ST method which explicitly takes into account ST even in regions where the interface's topology is complex, discuss its implementation and present its numerical performance. The method is introduced in the context of the finite volume, volume-of-fluid (VOF) approach for modelling multifluid flows by solving the Navier-Stokes equations, and is implemented in ISIS-CFD, the flow solver of the commercially available software package FINE^{TM}/Marine.

In ISIS-CFD, the volume fraction evolution equation is solved using compressive discretization schemes which do not require an interface reconstruction technique, such as the piecewise linear interface calculation (PLIC). The major advantage of such schemes is that they naturally treat complex interface topologies. Many classic ST methods (a thorough discusion can be found in [1]), approximate the interface's geometric quantities using the derivatives of the fluid indicator field (the volume fraction for VOF). Instead, the proposed ST modelling approach, utilizes a very versatile face-based marching cube (MC) algorithm (several examples of which are found in [2]) to generate an isosurface of the volume fraction, which we consider as an approximation of the actual interface. In turn the isosurface is used, firstly, to calculate the required interfacial geometric quantities required for ST and secondly, the regions where ST is enforced as a boundary condition by the ghost-fluid like method presented by Queutey and Visonneau [3].

The presentation is organized by presenting seperately the major components of the proposed method. First, we introduce the MC algorithm and demonstrate its capturing capabilities in simple test cases. Next, we discuss in detail the numerical scheme used for introducing ST in the Navier-Stokes equations. The numerical performance of the algorithm is evaluated through two simple test cases with and without automatic grid refinement, a static and a rising air-water bubble. Finally, we present results of a more demanding simulation, a small bubble (R=0.5 mm) interacting with the free surface (figure 1).

In conclusion, a surface tension method is introduced. The distinctive features of the method are the isosurface generation algorithm and its indirect coupling with the Navier-Stokes through ST. Besides the visually pleasing isosurfaces, comparisons with analytic and experimental results show the excellent numerical features and robustness of the proposed approach.

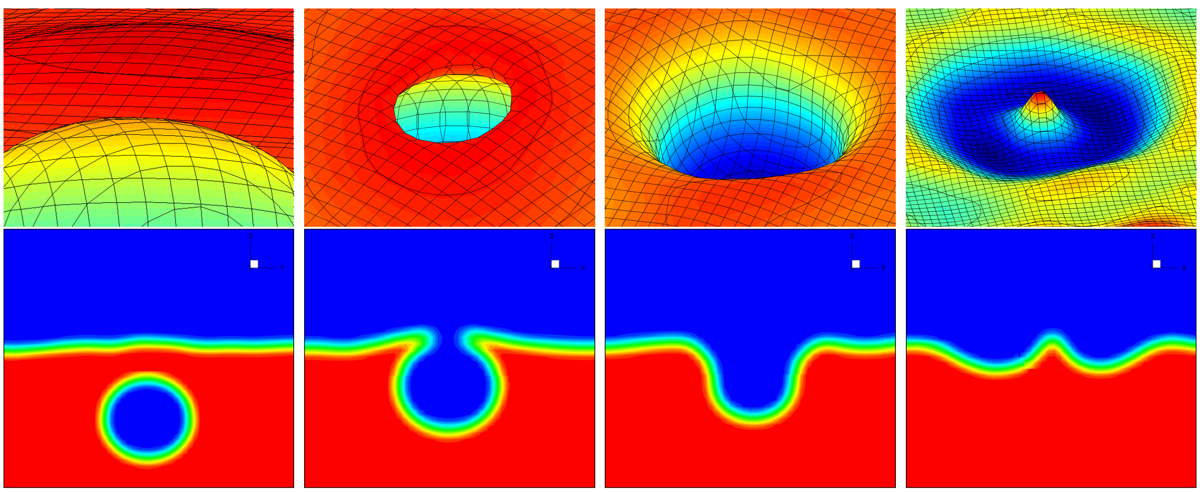

Figure 1: Close-ups of isosurfaces and volume fractions slice snapshots from a rising bubble-free surface interaction simulation. Isosurfaces colored by interface's relative height.

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