The first step towards extension of the Mass-Conserving Level-Set method to discretisations using general polyhedral control volumes.

F. Raees*, **D.R. van der Heul, C. Vuik**

Delft Institute for Applied Mathematics
Faculty of Electrical Engineering, Mathematics and Computer Science
Mekelweg 4, 2628 CD, Delft, The Netherlands.
*F.Raees@TUDelft.nl

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ABSTRACT

Simulation of immiscible two-phase flow requires the accurate representation of the interface between both fluids.

For those cases where the interface is required to be able to deform without any geometrical restrictions, two methods qualify for representing the interface location: The Volume Of Fluid (VOF) method and the Level-Set (LS) method. In the former, a color function $\Psi(\mathbf{x}, t)$ is used to identify the presence of either fluid. The interface location is only approximately defined: it will intersect those cells that have intermediate values of the colour function, but its exact location is unknown. In each time step the position of the interface is reconstructed within each cell that is intersected by the interface, under the assumption the interface is either aligned with the cartesian coordinate directions or locally planar, before it is advanced in time in a Lagrangian manner. In the latter method the interface position is indicated by a level-set (distance) function $\Phi(\mathbf{x}, t)$. The level-set function is advanced in time using a high resolution, nonoscillatory convection scheme.

The VOF method is very accurately mass-conserving, but the interface reconstruction, and the approximation of the local curvature of the interface to define the surface tension are very computationally intensive and involved. On the other hand, the LS approach provides an exact (up to discretisation order) representation of the interface and straightforward evaluation of the local properties of the interface, but it is by definition not mass conserving: Exact conservation of the level-set function does not imply conservation of mass.

In recent years an interest has developed in hybrid VOF/LS methods that combine the accurate mass conservation properties of the former with the advantage of an exact representation of the interface of the latter approach. Examples of these are the Combined Level Set Volume Of Fluid (CLSVOF) method of Sussman et al [3]. and the Mass-Conserving Level-Set (MCLS) method of Van der Pijl et al [2].

Although both examples seem to be very similar on the surface, the major difference is that the CLSVOF method basically combines the work involved in both the VOF and LS method, while the MCLS method avoids the computationally intensive interface reconstruction step of the VOF method. This is accomplished by the use of a function that *directly relates the VOF colour function* Ψ *to the LS function* Φ *and its gradient* as

$$\Psi = f\left(\Phi, \nabla\Phi\right), \tag{1}$$

without the need for an explicit reconstruction step.

The original formulation of the MCLS method was defined only for discretisation on (Cartesian) hexahedral grids, making its applicability limited.

In the current paper a start is made with the extension of the MCLS for discretisation on general polyhedral control volumes, that are used in today's industrial computational fluid dynamics analysis algorithms. The formulation of the MCLS for two-dimensional laminar viscous flow is discussed using a discretisation of the Navier-Stokes equations on an unstructured triangular grid, using some ideas from the CLSVOF defined on unstructured grids as discussed in [1, 3]. A comparison will be made between the original formulation and the unstructured formulation for a number of two-dimensional test cases.

References

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