Master Thesis Project (WI5005)
Section: Numerical Analysis

Volume-conserving FEM-based level-set method

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Description:

The level-set method [Osher and Sethian, 1988] is a technique, which is widely used to describe physical systems containing two different phases, such as the flow of oil and gas. In essence, an auxiliary function $\phi(x, y)$ is defined in the entire domain $\Omega \subseteq \mathbb{R}^2$ as the signed-distance from each point $x, y \in \Omega$ to the interface of interest Γ. The signed-distance is the minimum distance to the interface, whereby positive and negative sign is used to distinguish between the two phases. The interface is then implicitly given by the zero-contour of the level-set function, i.e. $\Gamma = \{x, y : \phi(x, y) = 0\}$.

A common problem in using the level-set method is loss of volume, which stems from numerical errors during the advection of the level-set function and the non-conservative nature of the level-set method. Within the finite-volume, finite-difference and discontinuous-Galerkin framework several approaches have been taken to eliminate this loss of volume, see Denner et al. [2014] for an overview and for example Raees et al. [2016]. Within the framework of the FEM-based level-set method recent work by Basting and Kuzmin [2014] eliminated the loss of volume.

In this Master Thesis Project, you will investigate the current state-of-the-art volume conserving level-set FEM-based methods and develop a new approach that builds on the current state-of-the-art volume conserving level-set FVM- and DG-methods, all within the framework of continuous-Galerkin finite-elements.

Approach:

During this project several tasks have to be completed, which are:

1. Literature research on level-set methods in general;
2. Literature research on current state-of-the-art volume-conserving level-set methods;
3. Literature report;
4. Formulation, analysis and implementation of the new volume-conserving level-set method(s);
5. Implementation of at least one of the current state-of-the-art approaches;
6. Comparison of the two or more volume-conserving level-set method(s);
7. Master Thesis.

References:

C. Basting, D. Kuzmin. Optimal control for mass conservative level set methods. Journal of Computational and Applied Mathematics, 270:343-352, 2014.

F. Denner, D.R. van der Heul, G.T. Oud, M.M. Villar, A. da Silveira Neto, B.G.M. van Wachem. Comparative study of mass-conserving interface capturing frameworks for two-phase flows with surface tension. International Journal of Multiphase Flow, 61:37-47, 2014.

S.J. Osher and J.A. Sethian. Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton-Jacobi formulations. Journal of Computational Physics, 79(1):12–49, 1988.

F. Raees, D.R. van der Heul, C. Vuik. A mass-conserving level-set method for simulation of multiphase flow in geometrically complicated domains. International Journal for Numerical Methods in Fluids, 81:399-425, 2016.