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A novel cutcell method for interfacial flows - application to phase change

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The discrete calculus of Morinishi [1] is leveraged to discretize diffusive and convective transport phenomena in scalar PDEs. Discrete cutcell operators on Cartesian meshes are designed to preserve the structure of the continuous operators, namely (1) the symmetry (skew-symmetry, resp.) of the diffusive (convective, resp.) transport operators and (2) discrete local and global conservation. The expressivity of Morinishi's calculus allows for a concise formulation of discrete operators for Dirichlet, Neumann and Robin boundary conditions. Validation are provided that assess the scheme's second order accuracy, stability and ability to accurately represent transfers across solid boundaries [2].
Moreover, the method is applied to a phase change problem where the normal motion of the interface depends on the jump in temperature gradient between a liquid and a solid phase. A set of two-dimensional Stefan problems where a level set method is used for capturing the interface between both phases are presented. The discrete cutcell method coupled with an implicit scheme for solving the heat equation and an inflow-implicit/outflow-explicit scheme [3] is used for solving the level set advection equation. Validation is performed against some analytical solutions of the classical Stefan problem, including dendritic growth and accounting for the surface tension effects. The Rayleigh-Bénard instability, where a regular pattern of convection cells appears as a fluid layer is heated from below, is also studied in this framework.

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