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Cut-cell stabilization based on a variational multiscale subgrid-scale model

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With an emerging interest in the use of immersed finite element methods, there is a need for new stabilized formulations. Stabilization methods often rely on the concept that stabilization of finite element schemes is closely related to capturing the scale interaction between the finite element solution, and the unresolved subgrid-scale solution [1]. The residual-based variational multiscale (R-VMS) model is a widely employed stabilization method, that can at the same time act as a subgrid-scale model for simulating turbulent flow. Attempts have been made to incorporate this model in immersed finite element fluid simulations [2]. However, in the derivation of the R-VMS models it is explicitly assumed that the subgrid scales vanish on element and domain boundaries. This assumption is violated in the case of immersed boundary conditions. Recently, the authors have proposed an R-VMS subgrid-scale model that does incorporate fine-scale element boundary contributions [3, 4]. This model was proposed in a discontinuous Galerkin setting, where the jumps provide access to fine-scale information on the element boundaries. An analogous approach may be adopted for cut-cell stabilization, since the weak satisfaction of boundary conditions offers direct access to the fine-scale solution on the immersed domain boundary. The theory underlying this modified subgrid-scale model will be presented, and its effectiveness as a stabilization technique will be demonstrated.

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