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A new class of generalized finite element spaces for problems with immersed boundaries

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In multiphase flows, free surface flows and also for diffusion problems with discontinuous density, interface forces or fluxes arise on free boundaries and the location of the boundary changes in time. We follow the idea of adapted finite element spaces for elements cut by the immersed interface in order to avoid computationally expensive remeshing or the introduction of artificial forces. Since immersed boundary forces and fluxes are directed quantities, the scheme is designed to approximate not only the solution but also the gradient at the interface appropriately.

Our approach is inspired by the Petrov-Galerkin weak formulation of the finite volume method. Within a finite volume formulation the boundary fluxes naturally arise. Therefore, the derived spaces directly take the shape of the boundaries into account. The resulting finite element spaces get then employed to the usual Galerkin formulation and therefore the discrete system is symmetric and intrinsically stable. In particular, there is no need for interior penalization to guarantee stability. This is, however, mandatory for most discontinuous Galerkin formulations. Finally, we show that the spaces obey even local conservation laws due to their relation to the finite volume formulation.

As numerical examples we consider diffusion problems and multiphase flow problems such as particle-fluid and fluid-fluid mixtures. A typical issue in particle-fluid flows are spurious oscillations of the pressure near the interface. Our computations show, that the oscillations could be eliminated without additional penalization terms. The results therefore demonstrate that the adapted spaces describe the physics of the discrete interface appropriately.

REFERENCES

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