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Scalable Iterative Solvers for Immersed Finite Element Methods

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Immersed finite element methods are useful tools to preclude expensive meshing operations for problems posed on complex [1] and/or scanned domains [2]. A common pitfall of immersed techniques is, however, ill-conditioning of the linear system [3, 4]. This impedes the convergence of iterative solvers, and often compels researchers to resort to direct solvers [5]. This hinders the efficient and inexpensive computation of solutions of large sparse systems, as the computational cost of direct solvers does not scale well with the size of the linear system, making them unsuitable for the increasingly large problems being solved by immersed methods, e.g. [6].

In [4] we have analyzed the fundamental cause of ill-conditioning of immersed finite element methods and, based on this analysis, in [7] we have developed a preconditioner that is tailored to immersed flow problems. We demonstrate that this preconditioner brings the condition number down to that of standard, mesh-fitting, finite elements, such that the linear system can be solved iteratively. Like standard finite elements, the conditioning of this preconditioned system still depends on the grid size however.

In this contribution we shortly describe the cause of the conditioning problems and the developed preconditioner, and extend this approach to investigate possibilities to apply the preconditioner as a smoother in a multigrid cycle to develop a scalable solver that is robust to both the grid size and how elements are cut.

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