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Stable unfitted finite element method for poroelasticity with weak discontinuity

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The traditional finite element method requires that the mesh must match with various discontinuous, which can significantly increase the difficulty of preprocessing for hydrodynamic coupling problems with complex boundaries and material interfaces. In such case, the finite element method using unfitted mesh is obviously more advantageous, however, this method also has certain problems, for example, irregular mesh cutting may lead to ill-conditioned coefficient matrix to appear, which in turn affects the accuracy and stability of the algorithm. The ghost penalty technique was proposed to overcome the ill-conditioning issue. Recently, an unfitted finite element was proposed for two-field poroelasticity problem, where stabilization terms based on the ghost penalty were developed. Material interfaces are even more difficult to deal with than the boundary as they require careful treatment of the weak discontinuity conditions as well as the mesh cutting stabilization. In this paper, we formulate an unfitted finite element for the poroelastic problem with both material interfaces and complex boundaries. A weak formulation based on the Nitsche's method was developed. Ghost penalty stabilization terms are designed for both sides of the elements intersected by the material interface. The performance of the proposed methodology is tested by several benchmark and practical hydraulic problems of complicated rock-soil mixtures. The numerical results demonstrate optimal convergence rates and low-level condition numbers independent of the mesh cutting.

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References

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