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High-Order Ghost Point Methods for Accurate Boundary Conditions in PDEs on Complex Domains

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Solving partial differential equations (PDEs) in domains with complex geometries is central to many scientific and engineering applications, yet it poses significant computational challenges, particularly in the accurate and stable imposition of boundary conditions. This talk presents high-accuracy discretization strategies for boundary conditions within the framework of unfitted boundary methods.

We introduce boundary discretization schemes based on the ghost point method. The approach extends the computational grid beyond the physical domain by introducing ghost points whose values are determined so as to enforce boundary conditions with high accuracy. In contrast to traditional techniques that assign ghost point values through local or one-sided extrapolation, our method adopts a coupled formulation in which ghost point values are solved simultaneously with neighboring interior and ghost points. This leads to an augmented linear system that significantly improves both accuracy and numerical stability.

To efficiently solve the resulting systems, we develop a specialized multigrid solver tailored to the presence of curved and irregular boundaries. The effectiveness of the proposed approach is demonstrated through numerical experiments on elliptic PDEs and its applicability is further illustrated in incompressible flow simulations, including dynamic configurations such as oscillating bubbles. In addition, we present recent extensions of the method to hyperbolic equations, highlighting its challenges for time-dependent, transport-dominated problems.

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