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CUT-CELL/EMBEDDED BOUNDARY METHODS FOR FLUID AND SOLID MECHANICS

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ABSTRACT

Interfaces are ubiquitous in computational science, in problems ranging from material boundaries to different physical phenomena and mathematical approximations in fluid and solid mechanics. In this minisymposium, we will focus on “cut-cell” methods, where a smooth background mesh is modified only in regions near a sharp interface. This approach has been applied in finite volume (“embedded boundary”), finite element (“Nitsche’s method”, primal methods), and finite difference (“immersed interface”) approaches. The challenges for these methods have traditionally been higher-order accuracy and stability in the presence of small or arbitrary cut cells.

For accuracy, questions arise around boundary representation, which ranges from simple approaches using grid line intersections, to more complex representations using splines, implicit functions, and constructive solid geometry. We will present results from several different approaches, and discuss the difficulties encountered using higher-order bases, curved boundaries, and compatibility with higher-order interior methods. For example: What is the “contamination” of a global solution when using less accurate boundary methods? And, is it possible to maintain global accuracy and convergence even with very complex boundaries?

The second challenge is around methods that are both higher-order accurate and demonstrably stable in the presence of small or arbitrary cut cells. For elliptic problems, stability implies positivity of matrix operators, norm-boundedness of solutions and eigenvalues, *etc*. Recent progress from both mathematical foundations and numerical linear algebra will be presented. Stability for hyperbolic problems is more subtle, in terms of time step restrictions and wave properties relative to a regular interior scheme. Traditional approaches address any time-step restrictions using cell merging (to avoid small volumes) or implicit methods, both of which have consequences for dissipation and preserving accuracy for wave-like phenomena and stability with moving boundaries. We will have several examples from more recent progress on mathematical theory to heuristics that are practically effective at maintaining both stability and accuracy, even when using explicit time integrator methods with very small cut cells.

We anticipate two sessions with a total of approximately 12 speakers.