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A Stable, High Order Accurate and Efficient Hybrid Method for Flow Calculations in Complex Geometries

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Constructing stable difference schemes on complex geometries is an arduous task. Even fairly simple partial differential equations end up very convoluted in their discretized form, making them difficult to implement and manage. Spatial discretizations using so called summation-by-parts operators have mitigated this issue to some extent, particularly on rectangular domains, making it possible to formulate stable discretizations in a compact and understandable manner. However, the simplicity of these formulations is lost for curvilinear grids, where the standard procedure is to transform the grid to a rectangular one, and change the structure of the original equation.

In this paper we reinterpret the grid transformation as a transformation of the summation-by-parts operators. This results in operators acting directly on the curvilinear grid. Together with new developments in the field of nonconforming grid couplings we can formulate simple, implementable, and provably stable schemes on general nonconforming curvilinear grids. The theory is applicable to methods on summation-by-parts form, including finite differences, discontinuous Galerkin spectral element, finite volume, and flux reconstruction methods. Time dependent advection–diffusion simulations corroborate the theoretical development.