\textbf{p-Refinement with Curvilinear Elements for a Discontinuous Galerkin Spectral Element Method Wave Equation Solver}

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\textbf{ABSTRACT}

There is a need to develop high order numerical methods to advance computational fluid dynamics, especially in the automotive, energy and aerospace fields. The discontinuous Galerkin spectral element method (DGSEM) provides higher accuracy compared to finite element schemes, providing exponential convergence to smooth solutions, but at higher cost per degree of freedom. Grid adaptivity mitigates the higher cost of high order methods, where \textit{h}-adaptivity splits elements and \textit{p}-adaptivity changes the local polynomial order on a per element basis. Both are guided by \textit{a posteriori} error estimators that evaluate the quality of the resolution within each element.

A parallel \textit{h/p}-adaptive DGSEM solver has been developed to solve the incompressible Navier-Stokes equations. It has been shown to scale well on high performance computing platforms for simple geometries. Dynamic load balancing is required for more complex geometries. Building on a DGSEM wave equation solver using \textit{h/p}-adaptivity and dynamic load balancing for rectangular domains, we present an extension to this wave equation solver to curvilinear geometries with \textit{p}-adaptivity. This work will contribute to enhancing the capabilities of the \textit{h/p}-adaptive Navier-Stokes solver to tackle direct numerical simulations for applications in aerodynamics.

A simulation of an acoustic scattering in a semi-annulus has been conducted to demonstrate the curvilinear extension, which uses a geometrical mapping from a reference square to a curved element. The implementation is tailored to perform \textit{p}-adaptivity in parallel. The simulation starts with polynomial order \textit{p} = 8 and adapts up to \textit{p} = 12 as directed by the error estimator. The results of the simulation are compared with benchmark solutions.