

Spacetime discontinuous Galerkin method for wave propagation simulation in complex media

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The dynamic wave propagation in many applications, e.g. elastodynamics, acoustics, and electromagnetics, can involve sharp wave fronts and complex wave scattering events. The spatial and temporal resolution of wave fronts and other details of the solution can be orders of magnitude finer than the scales of spacetime domain. Very accurate and efficient numerical methods are needed to resolve such fine solution details. Three specific challenges in time domain simulation of such problems are: 1) The very fine spatial resolution of solution details or geometries of a complex composite poses serious challenges in time step of explicit methods; 2) Due to the dynamic nature of wave propagation the spatial location of wave fronts and other solution details change in time, rendering static mesh adaptive operations ineffective. To efficiently capture such solution features dynamic mesh adaptive operations are required that adapt the mesh as simulation time progresses; 3) in wave propagation type problems, as opposed to structural dynamic regime, the same resolution of solution is required in time as in space. There are very few numerical methods that can accommodate arbitrary high temporal orders of accuracy in time, particularly enriching the order at the element level rather than for the whole spatial domain.

The spacetime discontinuous Galerkin method is a novel method that directly discretizes spacetime domain with unstructured grids that preserve a causality constraint. This enables a local and asynchronous solution strategy with linear solution complexity and local mesh adaptive operations in spacetime. Through examples we demonstrate how each of the aforementioned concerns are addressed by an adaptive formulation of the SDG method. We present numerical results from elastodynamic and electromagnetic problems. In addition, we discuss how this time domain approach can be used to characterize dynamic properties of composite materials. Numerical results demonstrating wave propagation in solids with complex microstructure patterns will be presented.