Efficient Explicit Time Integration for the Simulation of Acoustic and Electromagnetic Waves

Michaela Mehlin

Abstract

The efficient and accurate numerical simulation of time-dependent wave phenomena is of fundamental importance in acoustic, electromagnetic or seismic wave propagation. Model problems describing wave propagation include the wave equation and Maxwell's equations. Both models are partial differential equations in space and time. Following the method-of-lines approach we first discretize the model problems in space using finite element methods (FEM) in their continuous or discontinuous form. FEM are increasingly popular in the presence of heterogeneous media or complex geometry due to their inherent flexibility: elements can be small precisely where small features are located, and larger elsewhere. Such local mesh refinement, however, also imposes severe stability constraints on explicit time integration, as the maximal time-step is dictated by the smallest elements in the mesh. When mesh refinement is restricted to a small region, the use of implicit methods, or a very small time-step in the entire computational domain, are generally too high a price to pay.
Starting from explicit Runge-Kutta (RK) methods, we propose high order explicit local time-stepping (LTS) methods for the simulation of acoustic and electromagnetic wave phenomena. By using smaller time steps precisely where smaller elements in the mesh are located, these LTS methods overcome the bottleneck in explicit time integration caused by local mesh refinement, without sacrificing the explicitness, accuracy or efficiency of the original RK method.