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The Reverse Time Migration technique coupled with Interior Penalty Discontinuous Galerkin method.

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Seismic imaging is based on the seismic reflection method which produces an image of the subsurface from reflected waves recordings by using a tomography process and seismic migration is the industrial standard to improve the quality of the images. The migration process consists in replacing the recorded wavefields at their actual place by using various mathematical and numerical methods but each of them follows the same schedule, according to the pioneering idea of Claerbout: numerical propagation of the source function (propagation) and of the recorded wavefields (retropropagation) and next, construction of the image by applying an imaging condition. The retropropagation step can be realized accouting for the time reversibility of the wave equation and the resulting algorithm is currently called Reverse Time Migration (RTM). To be efficient, especially in three dimensional domain, the RTM requires the solution of the full wave equation by fast numerical methods.

Finite element methods are considered as the best discretization method for solving the wave equation, even if they lead to the solution of huge systems with several millions of degrees of freedom, since they use meshes adapted to the domain topography and the boundary conditions are naturally taken into account in the variational formulation. Among the different finite element families, the spectral element one (SEM) is very interesting because it leads to a diagonal mass matrix which dramatically reduces the cost of the numerical computation. Moreover this method is very accurate since it allows the use of high order finite elements. However, SEM uses meshes of the domain made of quadrangles in 2D or hexaedra in 3D which are difficult to compute and not always suitable for complex topographies.
Recently, Grote et al. applied the IPDG (Interior Penalty Discontinuous Galerkin) method to the wave equation. This approach is very interesting since it relies on meshes with triangles in 2D or tetrahedra in 3D, which allows to handle the topography of the domain very accurately. Moreover, the fact that the resulting mass matrix is block-diagonal and that IPDG is compatible with the use of high-order finite element may let us suppose that its performances are similar to the ones of the SEM.

In this presentation, we study the performances of IDPG through numerical comparisons with the SEM in 1D and 2D. We compare in particular the accuracy of the solutions obtained by the two methods with various order of approximation and the computational burden of the algorithms. The conclusion is IPDG and SEM perform similarly when considering low order finite elements while IPDG outperforms SEM in case of high order finite elements. Next we illustrate the impact of IPDG on the RTM, first through a simple configuration test (two-layered medium), then through realistic industrial applications in 2D.