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A finite-volume method for the 2D seismic wave propagation

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Seismic wave propagation has been investigated using various numerical methods as classical finite-element of finite-difference methods or boundary integral equations. Popular methods as the staggered-grid finite-difference one are based on the first-order form of elastic waves equations (velocity-stress hyperbolic system) in a similar way as for Maxwell equations. The local accuracy and efficiency of theses schemes are generally reduced when complex surface topography or internal curved interfaces are included in quadrangular meshes. In these cases, triangular meshes might lead to more flexibility.

We propose here a complete reanalysis of the finite volume approach based on unstructured triangular meshes. We perform a change of variables. Then, the system writes in pseudo-conservative form and the properties of the medium, which are constant in time but could depend on space variables, appears only in a diagonal matrix, operating on the time derivatives of the variables. The computational domain is discretized by a finite-element mesh. The unknowns are supposed to be constant on each control volume which is the elementary cell of the triangulation (formulation P0 of finite-element approach). All the components are defined at the center of the element showing that no staggering is necessary. The use of an unstructured triangular mesh allows an accurate discretization of the surface topography or curved interfaces and local refinement in some selected zones of the calculation domain.

The system is integrated on the control volume. The integration of the space derivatives reduces to numerical fluxes on the edges of the elements. The scheme is based on centered fluxes and a leap-frog scheme in time. For the treatment of the boundaries of the necessary truncated computational domain, i.e. artificial boundaries, we apply the perfectly matched layer technique (PML) on the initial triangular mesh. The PML layer is identified by its damping coefficients and there is no need to add a quadrangular mesh layer.For test cases containing a free surface, the numerical flux at the boundary is calculated by appropriate conditions on these particular edges.The validation of the method has been done for several test cases. The study of the propagation of an explosive source in a rectangular homogeneous infinite domain shows the nice behavior of the PML method. We have also studied the weathered layer test case proving how well the numerical scheme is performing for internal heterogeneities and for free surface condition. More complex geometries are possible and case-dependent. All these results show the good properties of this new finite volume method.