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Elastic wave propagation in inhomogeneous medium using the spectral element method

M. Stupazzini (1), F.J. Sánchez-Sesma (2)

(1) Department of Earth and Environmental Sciences LMU, Munich, Germany, (2) Instituto de Ingeniería UNAM, Mexico City, Mexico

The Spectral Element Method is a modern tool based upon a weak form of Galerkin's variational approach. It is a refinement of the classical and widespread Finite Element Method. The usual concepts of interpolation functions and numerical integration are kept. Other concepts as the introduction of Lagrange polynomials as interpolation functions constructed with nodes precisely at the Gauss-Lobatto-Legendre (LGL) integration nodes make the technique a really powerful tool in which exponential convergence is achieved.

The current SEM implementations consider the linear viscoelastic medium. However, in all cases homogeneity has been assumed for each spectral element and spatial variations in applications are modeled by step-wise constant elements. In many cases significant advantages may be achieved if the spatial variations of properties are allowed within the elements. This can be accomplished with relative ease as the spatial properties have to be sampled by the LGL points. For functional variation corresponding to polynomials less or up to the degree of the concerned element the integration is exact. Of course, if jumps in properties appear is better to set an interface.

The SEM is summarized herein considering explicitly in the formulation the spatial variations of the elastic Lamé's moduli and the mass density. The implementation was made to in a current code. In order to validate this approach we simulate elastic wave propagation in 2D within a medium with linear variation of wave velocity. In a medium like this one the rays from a point source are known to be circular. Moreover, the associated wave fronts are circular cylinders or spheres in two or three-dimensions, respectively. Thanks to these facts, simple analytical approximations for the corresponding 2D Green's functions have been developed (Sanchez-Sesma, Madariaga &

Irikura, 2001). Such analytical approximations are generalizations of the homogeneous Green's functions that use exact travel times and rely on the asymptotic ray theory to establish travel times and the geometrical spreading factors. That approximation accounts for both near-source effects and low frequencies. The agreement of simulations using SEM and the analytical solution is excellent.