

Low-rank Wave Propagation of Anisotropic Wave Modes

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Reverse-time migration (RTM) and full waveform inversion (FWI) have been the most popular topics in exploration seismology during the past decade. Both of these two techniques require accurate and efficient wave extrapolation operators. There are various ways to extrapolate the wavefield.

Conventionally wave extrapolation in time is done by finite-difference (FD) methods. FD methods require lower computational cost but suffer from dispersion artifacts. Spectral methods are a different approach to this problem with advantages in high accuracy and ability to suppress dispersions; however, they are more expensive to implement and only until recently were they afforded thanks to advances in high performance computing.

Based on Fourier transform, a time-stepping equation was introduced by Wards et al. (2008) to construct a space-wavenumber domain wave-propagator. Fomel et al. (2010) proposed to design wave extrapolation operators by approximating the mixed-domain propagator matrix symbol using low-rank decomposition. A low-rank algorithm selects a small set of representative locations and wavenumbers to approximate the matrix, which is significantly more efficient than conventional spectral methods and offers flexible controls over approximation accuracy.

To demonstrate the properties of low-rank wave propagation, numerical experiments have been carried out using exact phase velocities to propagate different wave modes in anisotropic media, such as VTI, TTI, orthorhombic and tilted orthorhombic models. A two-step time marching scheme was adopted to simulate wave propagation in the real number domain. By switching to a one-step time marching scheme, which requires implementation in the complex domain, larger steps can be afforded and computational cost is further reduced. The new scheme also enables absorbing boundaries which is required by RTM.

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