Near-surface Velocity Modeling through a Computationally Efficient Implementation of 1.5D Laplace-Fourier Full Waveform Inversion

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Abstract

Seismic data migration is a process that is influenced heavily by the kinematic properties of the velocity model used. For a successful migration, the velocity model must track accurately enough the complexities of the near-surface. We developed a fast Laplace-Fourier (LF) full waveform inversion (FWI) that operates under a 1.5D isotropic, acoustic medium assumption, to tackle the problem of initial velocity model building. The method works by inverting the full waveform (amplitude and phase) of refraction events, in virtual super shot gathers. These are formed after applying static corrections and stacking the traces of each offset bin within a common midpoint bin. The objective function consists of a data misfit function in the Laplace-Fourier domain, as well as of several other optional components. These include Laplacian regularization to control the smoothness of the resulting velocity model and L2-distance minimization of the result from a reference model to be used as prior model information in the inversion process. The objective function is minimized by a nonlinear conjugate gradients, producing a single 1D velocity model per each virtual super shot gather. The proposed approach is validated using synthetic data generated from a 3D velocity-gradient model, characterized by a strong velocity inversion at the top and two embedded velocity anomalies. The method starts from a velocity gradient as an initial model and it is able to recover the anomalies and the velocity inversion. The latter would have been difficult to obtain using first-arrival tomography, which highlights the value of full waveform approaches. The results show good correspondence with the ground truth model. The 1.5D approximation keeps the required numerical effort at affordable levels. Solving the LF version of the problem allows one to invert for a small number of frequencies, also helping to reduce the computational cost. Inversions happen independently per gather of input data, requiring very minimal communication when the workload is distributed over a computer cluster. Moreover, it is possible to offload forward modeling to graphics processing units (GPUs) for further execution speed gains. The resulting 1D models can be used to produce a 3D model to serve as a starting model for more accurate 3D FWI.