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Efficient Low-Rank Frequency-Domain Least-Squares Marchenko Imaging

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Abstract

Reverse Time Migration (RTM) excels at imaging complex structures and steep dips but creates artifacts due to its single-scattering assumption and adjoint operator use, with internal multiples degrading image quality. Removing multiples while preserving primary reflections is challenging, and current methods often fail. Marchenko-based approaches handle internal multiples but require extensive preprocessing and high computational cost. Least-Squares Migration (LSM), particularly LSRTM, boosts resolution and amplitude fidelity but increases computational load. Frequency-domain LSRTM (FLSRTM) cuts cost by processing spectral subsets but requires large storage for Green's functions and struggles with accurate internal multiple modeling. In this work, we propose the frequency-domain least-squares Marchenko imaging (FLSMI) method, using a multiple-free migrated image from Marchenko imaging as the reflectivity starting point. Marchenko-derived Green's functions, capturing more wavefield data, act as propagation operators in FLSMI, incorporating internal multiples to reduce ill-posedness and enhance image quality over FLSRTM. Storing Green's functions is challenging, but the SVD algorithm enables compact formats, and randomized SVD (rSVD) and compressed SVD (cSVD) offer efficient options. Thus, FLSMI with low-rank Green's functions via rSVD/cSVD yields high-quality imaging at lower computational cost, and a synthetic test confirms improved artifact suppression and resolution.