One-way wave-equation migration based on the Jacobi-Anger expansion for a medium with a strong lateral velocity variation

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Abstract

The one-way migration extrapolation operators, central to the recursive-extrapolation approach to seismic imaging, arise from approximate solutions to the two-way wave equation. This method has made an incredible contribution to the fields of seismic data processing and imaging. Unlike the reverse time migration (RTM), this method can only provide correct phases and amplitudes within limited propagating angles, especially for the strong velocity contrast media. While RTM is studied intensively across industries and academia, the one-way migration method still does not fully exploit its potentials, compared to the weaknesses of the RTM, such as huge memory costs, low efficiencies, and low-frequency artifacts. However, seismic depth migration by downward continuation using the conventional one-way wave-equation approximations has three shortcomings: handling evanescent waves, limitations in imaging large angles and stability on the one-way propagator.

In this work, we present an alternative scheme to alleviate the mentioned drawbacks and achieve a stable and affordable one-way equation depth stepping migration algorithm. First, we use the spectral projector to suppress the evanescent modes in an arbitrary laterally varying velocity model, then the coupled Schulz iteration scheme is applied to the Helmholtz operator to obtain the vertical wavenumber. Finally, a novel algorithm is presented to approximate the exponential matrix operator through the Jacobi-Anger expansion. The construction of the one-way propagator proposed in this work involves complete matrix multiplication, which is a distinct feature of this scheme and is suitable for efficient implementation.

The impulse response exhibits the better performance of our proposed novel algorithm over the conventional method based on the Taylor series expansion and the advantage over conventional one-way migration algorithms in describing the wavefield propagation of large angles in a medium with a strong lateral velocity variation. The post-stack depth migration result of the SEG/EAGE salt model and the pre-stack migration result of the Marmousi model further illustrates the superiority of our scheme in imaging the complex and fine-scale structures compared with the conventional one-way migration methods.