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Applications of Kirchhoff Least-Squares Migration: Towards Reservoir Imaging

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ABSTRACT

Objectives Seismic migration is designed to map the acquired reflection energy into a structural image of the changes in the subsurface model parameters. In this process, the seismic data, i.e. the primary reflections, are modelled as linear functions of the subsurface reflectivity and a migrated image is obtained by applying the adjoint (not the inverse) of the forward operator to the data. This migrated image is thus an approximation of the true reflectivity: uneven illumination of the subsurface and deviation from the proper imaging inversion operator cause artefacts, which are more evident in regions with complex geological structure and wave propagation. Procedures A formal inversion procedure based on a least-squares fit of the data aims to remove the migration artefacts and improve the amplitudes of the imaged reflectors. However, this is an expensive process because of its iterative nature. We present the practical benefits of implementing a Kirchhoff least-squares migration in a non-iterative fashion, often known in the literature as migration deconvolution. The linear nature of this imaging problem makes it possible to estimate non-stationary filters that remove the effects of the migration process and approximate the least-squares inversion result. The estimation of these spatially varying filters requires a cascade of Kirchhoff migration, modelling and re-migration. We have found the method to be robust, stable and computationally efficient for real data scenarios. Results We demonstrate the migration artefacts in question using a known synthetic dataset and show the benefit of applying our Kirchhoff least-squares migration deconvolution approach to help remove these artefacts. We then apply this process to datasets from the North Sea and offshore Gabon, highlighting improved imaging in complex areas, including a focus on the uplift of subsequent AVO and other reservoir-related attributes derived from pre-stack depth imaging. Conclusions The images obtained from the inversion show more balanced amplitudes and are also significantly denoised with respect to both the random (speckled) noise and the more coherent (swing) noise originating directly from the migration operator. As an immediate consequence, the estimation of reservoir-related AVO attributes, which are particularly sensitive to the illumination and noise level in the image, are noticeably enhanced.