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On the application of true-amplitude DMO

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ABSTRACT

Constant-velocity, true-amplitude migration to zero offset (MZO) is broken into two cascaded operations: (a) standard normal moveout (NMO) and (b) true-amplitude dip moveout (DMO) corrections. The output of the sequence NMO and true amplitude DMO applied to a constant-offset (CO) section is a simulated zero-offset (ZO) section, in which the geometrical spreading of primary reflections is the same as would be observed in a real experiment. For constant velocity, 3-D true-amplitude DMO can be carried out by two-dimensional, in-line Kirchhoff-type stacking. Moreover, both the stacking curve and weights are given analytically by means of simple formulas. For inhomogeneous media, we extend the algorithm by replacing both in the previous stacking curve and in the weight formulas the original constant velocity by the NMO velocity at the output point. At least for mild lateral velocity variations, this approach offers an efficient approximation to full MZO as it avoids expensive dynamic ray tracing computations. Synthetic and real seismic data examples are presented.

INTRODUCTION

Zero-offset simulation is required before post-stack migration to fulfill the exploding reflector model imaging condition. As pre-stack migration is a far more expensive process compared to post-stack migration, the effort of accurately simulating a zero-offset section is justified. In fact, the main objective of true-amplitude MZO is exactly to provide a stack of ZO sections such that a further application of true-amplitude post-stack depth migration yields the result that would be obtained by true-amplitude depth migration applied directly to the original data.

For a constant-velocity background, true-amplitude MZO can be performed in one step or may be split into the two independent processes of normal moveout (NMO) and true-amplitude dip moveout (DMO). True-amplitude MZO or DMO can be conveniently carried out as a weighted, Kirchhoff-type summation in which the stacking curves and weights are given by simple analytic formulas. More explicitly, it has recently been

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shown (Tygel et al., 1998) for true-amplitude DMO in the case of 2.5-D geometry

$$V(\xi_0, t_0) = \frac{1}{\sqrt{2\pi}} \int_A d\xi \; K_{DMO}(\xi; \xi_0, t_0) \, D_-^{1/2} U_n(\xi, t_n) \Big|_{t_n = \tau_{DMO}(\xi; \xi_0, t_0)} , \qquad (1)$$

where $U_n(\xi, t_n)$ denotes the NMO corrected CO section as a function of midpoint and NMO time (ξ, t_n), and $V(\xi_0, t_0)$ is the simulated ZO output placed at the coincident source-receiver location and ZO time (ξ_0, t_0). Also, $D_-^{1/2} U_n(\xi, t_n)$ is the anti-causal half derivative with respect to NMO time t_n, namely

$$D_-^{1/2} U_n(\xi, t_n) = \frac{1}{2\pi} \int_{-\infty}^{\infty} d\omega \; e^{i\omega t_n} \, |\omega|^{1/2} \; e^{-i\frac{\pi}{4}\mathrm{sgn}(\omega)} \; \hat{U}_n(\xi, \omega) \; , \qquad (2)$$

The true-amplitude DMO is designed to replace the geometrical-spreading of primary reflections in a given common-offset section by the corresponding one that would be observed in an actual zero-offset section. The geometrical spreading is a function of the reflector's dip and curvature.

Expression (1) will be applied to a simple synthetic example to verify correct amplitude recovery. We next adapt the algorithm to use it in a real data example. This is done by replacing the constant velocity in the weighting function by the NMO velocity of the point in the simulated ZO section where the output is to be placed. This simple and inexpensive adaptation is, in general, not expected to give rise to significant dip mispositioning and, moreover, for mild velocity variations, it provides reasonable geometric spreading compensation.

An important issue when dealing with amplitude preserving processes is spatial aliasing. As is well known (see, e.g., Yilmaz, 1987, Section 4.3.5), spatial aliasing arises for dips dt/dx in which

$$\frac{dt}{dx} \geq \frac{1}{2F_{max}\Delta\xi} \; , \qquad (3)$$

where F_{max} is the maximum temporal frequency in the data and $\Delta\xi$ is the spatial sampling rate. Application of Kirchhoff-like methods has to be accompanied by anti-aliasing filters. These are essentially dip-dependent, temporal-frequency filters which have the net effect of reducing the amplitudes at greater dips. As a consequence, the geometrical-spreading compensation for the true-amplitude DMO proposed here, should fail for dips that satisfy condition (3).

Coarse spatial sampling in the short offset range can also limit the ability of the method, particularly for dealing with geometrical-spreading compensation. This is simply because in this range, dips are coarsely sampled in the impulse response, the problems being more serious for larger times and velocities. As an alternative, we may consider either to spatially interpolate the data or to restrict the application of this technique only to larger offsets. Also 3-D data can usually pose more severe problems of coarse spatial sampling. In this case, interpolation cannot be avoided.

CONCLUSION

An effective, computationally simple constant-velocity true-amplitude DMO of Kirchhoff type, has been successfully applied to real data with moderate lateral velocity variation. The true-amplitude feature of the method guarantees that in the simulated ZO section, CO geometrical-spreading factors of primary reflections are automatically replaced for the corresponding ones that would be observed in a true ZO experiment. True-amplitude DMO as presented here may offer a cheaper alternative to full (dynamic ray tracing based) true-amplitude MZO in AVO studies.

One difficulty of true-amplitude DMO/MZO is related to coarse spatial sampling, which may degrade image quality and reliability of AVO curves. Assuming that the AVO curve is independent of frequency, AVO analysis of dipping reflectors can be restricted to an appropriate non-spatially aliased frequency band, so that the problem of low spatial CMP sampling in offset domain is minimized. Also, true-amplitude processing in the near offset range and in 3D data will normally demand fine interpolation.

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PUBLICATIONS

Detailed results have been presented at the Karlsruhe Workshop on Amplitude-Preserving Seismic Reflection Imaging and were published in the Special Issue of Journal of Seismic Exploration (Oliveira et al., 1997).