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5D Interpolation Using Azimuth Moveout (AMO) and Offset Vector Tiles (OVT)

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SUMMARY

Azimuth Moveout (AMO) is wave-equation operator that can be effectively applied to interpolate and regularize 5-D seismic data and improve the accuracy, illumination and imaging of structurally complex targets. AMO is strictly derived from the wave equation and therefore carries the correct kinematic, phase and amplitude transformation. The dipping events are moved correctly when transforming or interpolating the data and diffractions are preserved in a manner that is consistent with the wave equation. This property sets AMO apart as a seismic interpolator from more conventional ones. The AMO operator rotates the azimuth and modifies the offset of 3-D prestack data. It is analytically derived by cascading the forward and inverse 3-D DMO.

Traditionally, AMO was designed to address the marine acquisition shortcomings, and regularize common azimuth data. Typical implementation in time-space domain or frequency-wavenumber domain were primarily designed for 4-D data output. The recent focus by exploration and production companies on wide azimuth data both onshore and offshore creates the need to extend the AMO implementation to 5-D, by using offset vector tiles (OVT) to control the output geometry.

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Traditionally, AMO was designed to address the marine acquisition shortcomings, and regularize common azimuth data. Typical implementation in time-space domain (Kirchhoff type) or frequency-wavenumber domain (Fourier type) were primarily designed for 4-D data output. The recent focus by exploration and production companies on wide azimuth data both onshore and offshore creates the need to extend the AMO implementation to 5-D, by using offset vector tiles (OVT) to control the output geometry. Also recent interest in using Diffraction Imaging for imaging and delineating fracture fields in unconventional shales or fractured carbonates puts a premium on workflows that preserve diffractions. The land examples provided in this paper demonstrate the success of applying AMO to conventional land 3-D data.

Introduction

AMO is a partial pre-stack migration operator, and can be effectively applied to interpolate and regularize seismic data. The operator (Biondi et al., 1998) is strictly derived from the wave equation and therefore carries the correct kinematic, phase, and amplitude transformation. The dipping events are moved correctly when transforming or interpolating the data, in a manner that is consistent with the wave equation, and thus diffractions are better preserved than after normal or flex binning. Chemingui and Biondi (1999) propose to regularize 3-D datasets with a method they call Inversion to Common Offset ICO), which consists of regularizing the data into a number of common offset-and-azimuth gathers with azimuth moveout. Cary (1999) comments that the issue with ICO is obvious to anyone who has tried to form them from normal 3-D land data (or marine OBC data) that is acquired with orthogonal shot and receiver lines, there is no way to choose the offsets and azimuths in a way that yields a trace at each CMP location. The problems with common-offset-and-azimuth gathers stem from the fact that polar coordinates are being used to gather the data, but Cartesian coordinates are used to acquire the data. This leads to offset vector tiles (OVT) gathers, which are simply the Cartesian coordinate version of common-offset and azimuth gathers.

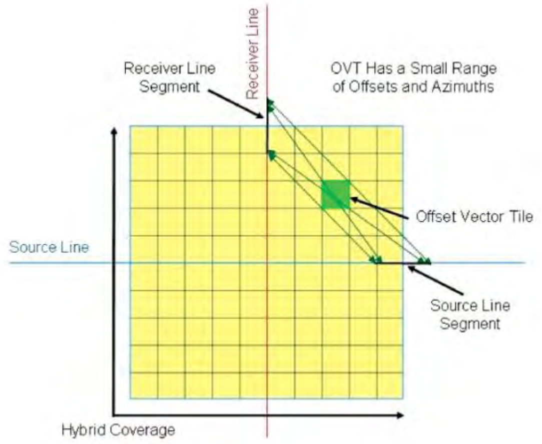

Figure 1: Offset vector tiles representation in an orthogonal land survey.

The concept of using vector offset bins was independently by Vermeer (2000) under the name offset vector tile (OVT) and by Cary (1999) under the name common offset vector (COV). For a number of standard survey designs, the vector offset bin dimensions can be chosen such that each bin defines a single fold cube over the survey area populated with traces of similar offset and azimuth.

Azimuth Moveout Theory

AMO transforms data with a vector offset **h1** into equivalent data with vector offset **h2** where the vector offset represents the directional segment between a seismic source and a receiver. In other words, AMO can transform a trace recorded with a source and receiver positioned at $x_{s1},y_{s1},x_{g1},y_{g1}$ into a trace recorded with a source and receiver positioned at $x_{s2},y_{s2},x_{g2},y_{g2}$. The kinematics of the AMO operator is exact only for constant velocity. Therefore, in the presence of severe velocity variations, the average of the reflections must be localized in offset and azimuth to avoid degrading the coherency in the stack. The analytical expression for the AMO operator (Biondi et al., 1998) is

$$t_0^2 = t_i \frac{h_o}{h_i}\left(\frac{h_i^2 \sin^2(\theta_i - \theta_o) - D^2 \sin^2(\theta_o - \phi)}{h_o^2 \sin^2(\theta_i - \theta_o) - D^2 \sin^2(\theta_i - \phi)}\right) \quad (1).$$

Where t_0 is the output time before inverse NMO, t_1 is the input time after NMO, h0, h1 are the respective offsets, D is the midpoint difference between input and output traces, and the rest represent projection angles of the offset vectors and the rotation between them. Figure 2A from Fomel (2003) shows the kinematics of the AMO operator, the green lines represent the movement of the input time samples to form the purple line which in turn gets summed into a single output value. Figures 2B and 2C show the application of AMO to interpolate a common midpoint (CMP) gather.

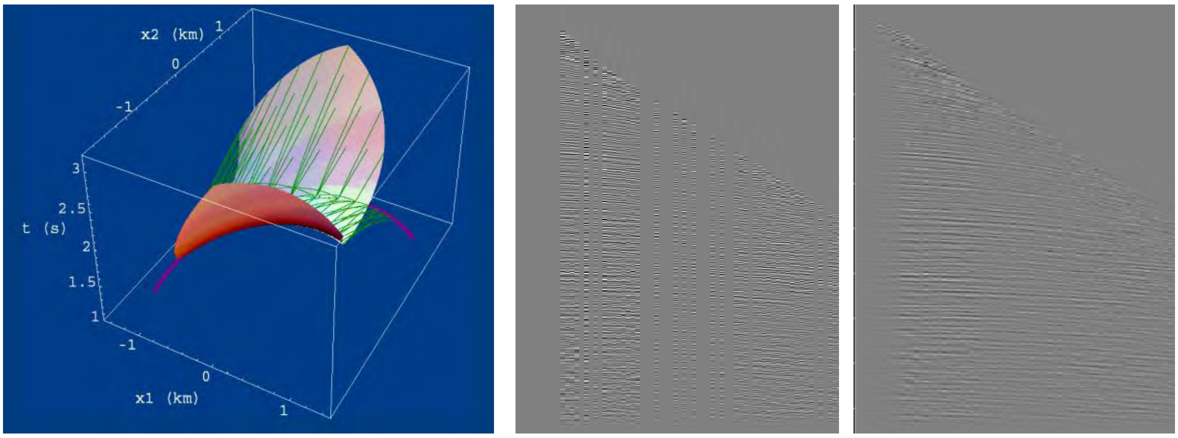

Figure 2: (A) Kinematics of the AMO operator from Fomel (2003). Panels B and C show the application of the AMO to interpolate a common midpoint gather.

Conclusions

We present a new AMO implementation designed to interpolate in 5-D wide azimuth data (OBC, land, marine), by using offset vector tiles (OVT) to control the output geometry. Azimuth Moveout (AMO) is wave-equation operator that can be effectively applied to interpolate and regularize 5-D seismic data and improve the accuracy, illumination and imaging of structurally complex targets. AMO is strictly derived from the wave equation and therefore carries the correct kinematic, phase and amplitude transformation. The dipping events are moved correctly when transforming or interpolating the data and diffractions are preserved in a manner that is consistent with the wave equation.

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