

P061 AN ALGORITHM FOR SEMI-AUTOMATED 3D HORIZON VELOCITY ANALYSIS

AUTHOR(S)

E.KURIN and V.GLOGOVSKY

Address

GeoTechSystem, 13/2 Ordjonikidze Ul., Moscow, Russia

Abstract

Accurate computation of reflected traveltimes is a critical issue for the depth imaging [4]. In order to account for wide-azimuth distribution of source-receiver pairs, the optimization with respect to more than one traveltime surface parameter is usually required thus making difficult algorithms' application to processing/imaging of large data volumes. When making the horizon-consistent analysis of traveltimes, a detailed information about zero-offset time surface picks, obtained in real-time with up-to-date interactive facilities, can significantly enhance the analysis accuracy and performance. We present a 3D horizon-consistent velocity analysis algorithm, where the number of sought-for parameters reduces to one. Once implemented as interactive software, the algorithm enables to reduce the processing/imaging turnaround time yet providing accurate traveltimes for a wide range of datasets.

Introduction

The determination of reflected traveltimes for 3D seismic data has been an urgent research issue for the last years. There is a number of works aimed at determination of the traveltimes from seismic data. Some of the algorithms represent one, or another, form of the iterative migration velocity analysis, as others make direct traveltimes determination in the time domain. In the present study, we make the analysis in the time domain only.

Let us consider a simple subsurface model with one dipping reflector defined by the equation

$$-\alpha x - \beta y - \gamma z + \delta = 0, \quad \alpha^2 + \beta^2 + \gamma^2 = 1. \quad (1)$$

Let the coordinate system origin coincide with a CMP. The traveltime of the reflected event with the source at $(-x, -y)$ and the receiver at (x, y) is given by the formula

$$t(x, y) = \sqrt{t_0^2(0,0) + 4 \frac{1-\alpha^2}{V^2} x^2 + 4 \frac{1-\beta^2}{V^2} y^2 - 8 \frac{\alpha\beta}{V^2} xy}, \quad (2)$$

where V stands for the velocity in the layer between the free surface and the reflector [2].

As for the applicability of the formula (2) to the layered media with various layer thickness/velocity combinations, it has extensively been studied for the last thirty years both theoretically and using numerical modeling, as well as real data analysis. In 3D, applicability conditions are generally the same as those for 2D, i.e. traveltimes can be described with the formula (2) for a great many of datasets. At least, the traveltimes parameterized with (2) can

feed an inversion scheme aimed at building an initial velocity-depth model, which can iteratively be improved with other methods.

Therefore, we assume that the traveltime surface can be described in terms of (2) by three independent parameters: α , β , and V , or in terms of three coefficients standing at x^2 , y^2 , xy . From (2) it follows that the analysis process consists in searching for these three parameters. The ‘‘sector analysis’’ approach combined with mixing traces belonging to adjacent CMP’s, described in [1], has become the basic one for practical implementations in seismic processing software. However, such methods suffer from low fold and irregular distribution of traces in conventional land-3D datasets. The use of present-day interactive facilities enables to employ the detailed information about the zero-offset time surface thus making it possible to reduce the search to the one-parameter analysis using all available traces.

Method

Let us transform (2) using the expression for the zero-offset surface $t_0(x, y)$

$$t_0(x, y) = t_0(0, 0) - \frac{2\alpha}{V}x - \frac{2\beta}{V}y. \quad (3)$$

The gradient of $t_0(x, y)$

$$\frac{\partial t_0(x, y)}{\partial x} = -\frac{2\alpha}{V} \quad (4a)$$

$$\frac{\partial t_0(x, y)}{\partial y} = -\frac{2\beta}{V}. \quad (4b)$$

Substituting (4a) and (4b) into (2) and reducing the terms, we obtain

$$t(x, y) = \sqrt{t_0^2(0, 0) - \left(\frac{\partial t_0(x, y)}{\partial x}x + \frac{\partial t_0(x, y)}{\partial y}y \right)^2 + 4 \frac{x^2 + y^2}{V^2}}. \quad (5)$$

Hence, if we are able to estimate the $t_0(x, y)$ gradient, V remains the only parameter to determine. In the case of a one-layer model, V has a clear physical meaning as the interval velocity, as for the real multi-layer models, V and the $t_0(x, y)$ gradient are just coefficients to parameterize the observed traveltimes.

Summarizing, the algorithm consists of the following basic steps:

1. Produce a raw stack cube with a priory NMO.
 2. Select a horizon to study and pick its zero-offset times; build and smooth a zero-offset time surface from these picks; compute the gradients.
 3. Run the line-by-line/point-by-point analysis as follows
 - scan the values of V with a given increment and apply the semblance operator to the traces corrected with NMO defined by (5) for every V_i
 - find V_{max} providing the maximum semblance value,
 - restack traces in the vicinity of the studied horizon, with NMO defined by V_{max} and by the $t_0(x, y)$ gradients;
-

- improve $t_0(x, y)$ picks, smooth, and re-compute the gradients.
4. Repeat the step 3 if necessarily.

Example

In order to illustrate the application of the algorithm, we have defined a velocity-depth model (Figure 1) and produced a synthetic dataset with a 3D ray-tracing program followed by convolving the output traveltimes with a given wavelet. The interval velocity changes from 1500 m/sec in the first layer to 2500 m/sec in the second one thus providing the ray-bending effect enough to distort the quasi-2D settings. Figure 2 shows three successive CMP gathers.

Figure 3 shows the velocity analysis for the CMP # 74 in progress. The top screen shows the inline section of the cube; the horizon in study is marked in black. The middle screen shows the horizon-consistent velocity spectra for the studied horizon up to the given CMP. The bottom screen shows the NMO-corrected event, with NMO parameters estimated at the previous iteration. In the display, traces are sorted by their offset values. Traces from nine (3 in-line by 3 cross-line) adjacent CMP's are mixed to provide better fold for the semblance operator. When mixing, the difference in traces' zero-offset times is taken into account.

For the comparison sake, Figure 4 shows the conventional 2D velocity analysis process for the same inline.

Conclusions

The algorithm for semi-automated 3D horizon velocity analysis has been developed. The algorithm's main feature is that it reduces multi-parameter optimization to one-parameter optimization iterations. This is done by using the detailed information about a zero-offset time surface for a studied horizon. Zero-offset time picks are updated during the analysis process.

The algorithm enables to improve both the accuracy and the performance of the analysis, which can be made at every point of a 3D survey with proper interactive quality control thus providing a dense grid of traveltimes to feed a kinematical inversion scheme.

References

- [1] Lehmann, H.J. and Houba, W., 1985, Practical aspects of determination of 3-D stacking velocities: *Geophysical Prospecting*, V33, No 1, p.34-51.
- [2] Glogovsky, V.M. and Meshbey, V.I., 1977, Three-dimensional seismic surveys and the methods for three-dimensional data processing, Moscow, VNIIOENG, p.7-14 (*in Russian*).
- [3] Neidell, N.S. and Taner, M.T., 1971, Semblance and other coherency measures for multichannel data: *Geophysics*, V36, No3, p.482-497.
- [4] Jones, I.F., 2003, A review of 3D PreSDM model building techniques: *First Break*, V21, p.45-58

Figures

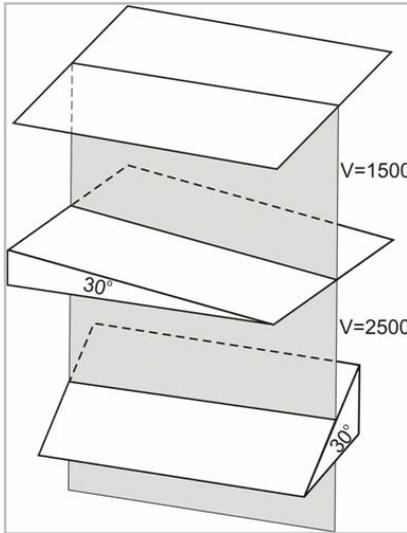


Figure 1. Test velocity-depth model

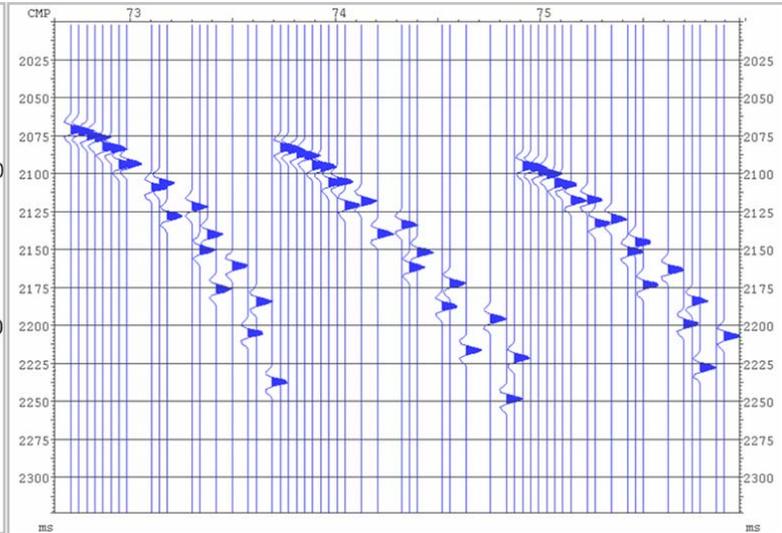


Figure 2. Synthetic traces modeled based on the given velocity-depth model. Close-up on events corresponding to the second horizon.

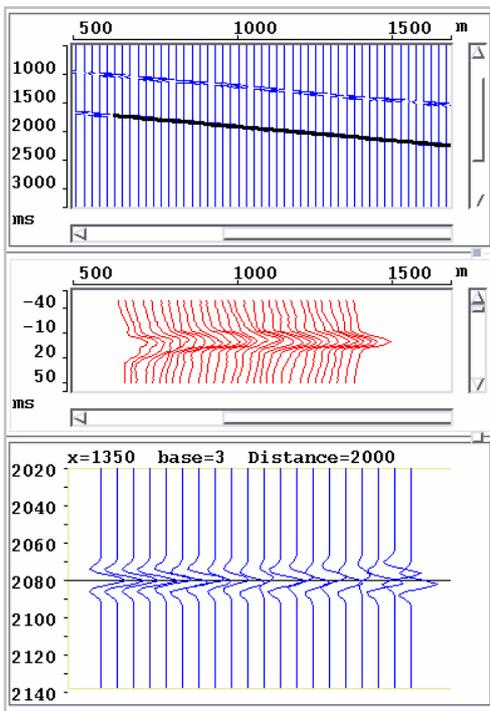


Figure 3. 3D horizon velocity analysis in progress.

Top: inline section of the stacked cube.

Middle: horizon-consistent velocity spectra.

Bottom: NMO-corrected event with (3x3) trace mixing

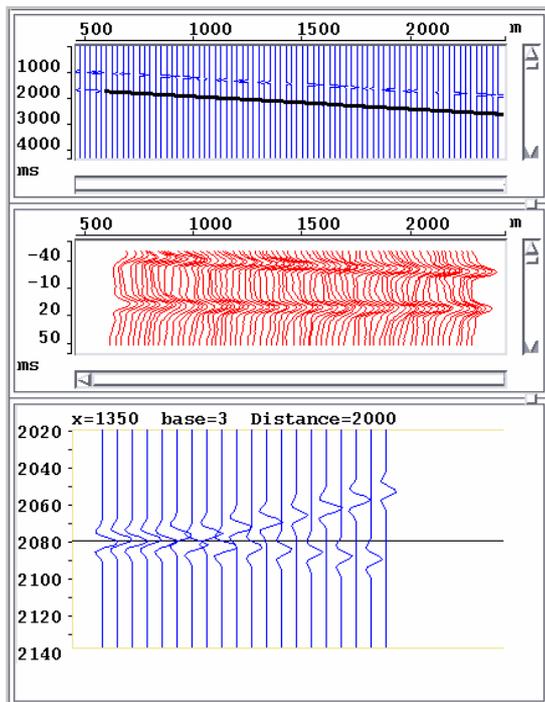


Figure 4. 2D horizon velocity analysis applied to the 3D synthetic dataset