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Kirchhoff-type Pre-stack Time Migration Using the CRS Stacking Operator

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SUMMARY

The Common Reflection Surface (CRS) stack method was developed to simulate ZO (zero-offset) staked sections from multi-coverage datasets. However, stacked data plus post-stack migration may loss quality in structural complex geological environments. In order to obtain high-quality images, in this work is presented an application of the CRS stacking operator for pre-stack time migration (PSTM). This new method called combines the classical Kirchhoff migration with the CRS operator, that is, for each sample point to be migrated with the Kirchhoff migration operator a beam-type stacking is performed of the locally coherent events using the CRS stacking operator. To test the reliability the CRS-beam PSTM is applied to expressively crooked seismic data. A comparison with the result of the Kirchhoff PSTM reveals that this new method produces improved image.

Introduction

As an alternative to the classical seismic stacking CMP method (NMO/DMO/stack), it was introduced the multi-parameter stacking method called Common Reflection Surface (CRS) stack (Jäger et al., 2001). In general, the application examples show that the ZO (zero-offset) stacked sections resulting from the CRS stacking process present a good quality with a higher signal-to-noise ratio and better delineation of complex structures, mainly reflectors with curvatures and steep dips.
In order to apply the CRS method directly for migration in Tassini et al., (2011) it was presented an application of the CRS stack method for pre-stack time migration. Following a similar approach, Garabito et. al., (2012b) introduced a new pre-stack depth migration method using the CRS operator for beam type stacking during the Kirchhoff-type migration process.
In this work I present a short review of theoretical aspects of the Kirchhoff-type pre-stack time migration based on CRS stack concepts. This migration method called CRS-beam PSTM incorporates the main advantages of the CRS stack method; therefore, it produces high quality results. Usually the standard pre-stack time migration methods produce poor results when applied to crooked-line data. In this work I show that CRS-beam PSTM produces also good results even in strongly crooked-lines data.

Kirchhoff-type PSTM using the CRS operator

The pre-stack time migration method presented here combines the Kirchhoff migration and the CRS stack method. As in the beam steering migration methods, the hyperbolic CRS stacking operator is used to perform the beam stacking of the locally coherent events with high coherence, i.e., events with particular slope and curvature that come from CRS attributes. The CRS-beam PSTM can be expressed by the following modified Kirchhoff-type migration integral (Garabito et al., 2012b):

$$I(M) = \frac{1}{\sqrt{2\pi}} \int_A d\xi \, w(\xi, M) \int_{A_L} d\xi_L \, D\left[U\left(\xi, \tau_D(\xi, M); \xi_L, t_{CRS}\right)\right], \qquad (1)$$

where $I(M)$ is the migrated amplitude for a point M in the output time section, i.e. the apex of the hyperbola. The function $U(\xi,t)$ denotes the input data (e.g. common-offset or CO), ξ is the configuration parameter and t is the two-way time. For the second integral the summation curve is defined by CRS operator in the vicinity of the trace amplitude to be migrated, located on the diffraction curve. The parameter ξ_L is the position of the trace within beam stacking aperture A_L. The CRS operator used for the beam stack is a hyperbolic travel time approximation represented by:

$$t_{CRS} = t_{CRS}(\xi_L, h; \alpha, K_{NIP}, K_N). \qquad (2)$$

The three kinematic CRS attributes are the emergence angle of the central ray (α), the wavefront curvature of the normal wave, (K_N), and the wavefront curvature of the normal incident point wave (K_{NIP}). Before applying the CRS-beam PSTM, these three CRS attributes should be determined from pre-stack data by means of multidimensional global optimization taking as objective-function a coherence measure (semblance). For each point M of the time migrated section, the external integral of Eq. (1) is evaluated summing the beam stacked amplitudes along the diffraction curve, $\tau_D(\xi,M)$, inside the aperture A. The amplitudes to be summed are then weighted by the function $w(\xi,M)$ in order to remove the effect of the geometrical spreading loss. Repeating this operation to all output points, M, the result is the migrated section. For the 2.5D case, the operator D corresponds to half-derivative time operator of the analytical input data.

Application in crooked-line data

The CRS-beam PSTM was applied in a crooked-line dataset acquired recently in a Brazilian Basin using a vibroseis seismic source. The processing of the data began with the geometry, trace edition, static correction and so on, until the residual statics. In Figure 1 the red curve represents the position of the sources, the dispersion of the midpoints are plotted in magenta and the processing line in blue. The highlighted area shows a strong dispersion of the midpoints.

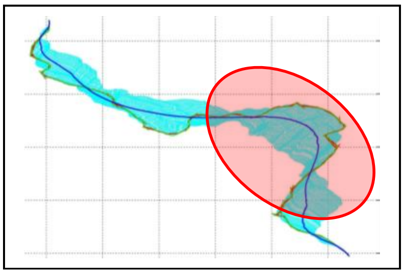

***Figure 1**: Crooked-line. CMP dispersion (magenta), source line (red), processing line (blue).*

In Figure 2a is the result of the classical Kirchhoff PSTM with strong migration artifacts produced due to high dispersion of the data. Before the application of the CRS-beam PSTM the CRS attributes are determined from the pre-stack data by applying the global optimization strategy presented in Garabito et al., (2012a). In Figure 2b is the result of the CRS-beam PSTM, where the artefacts were attenuated and the image quality was improved.

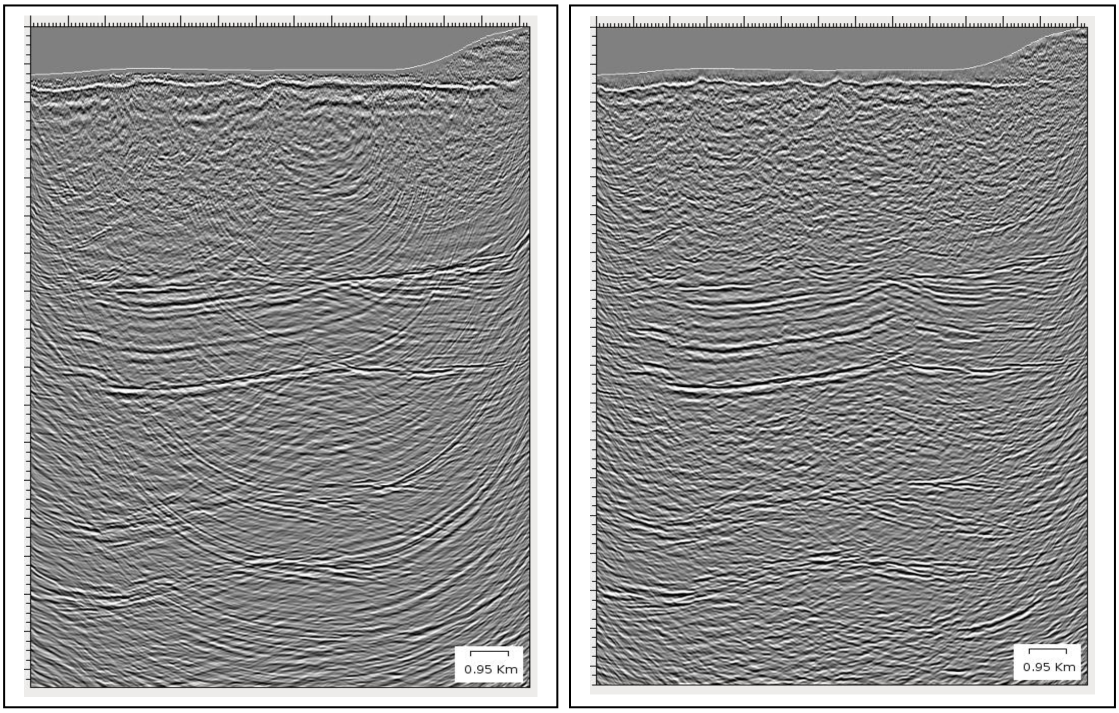

Figure 2*: PSTM images of a crooked seismic line. a) Migrated section from the Kirchhoff PSTM and b)Migrated section resulting from the CRS-beam PSTM. The migration artifacts in the middle part of the Kirchhoff migration image are produced due to high midpoint dispersion.*

Conclusions

The Kirchhoff PSTM produces poor result in the crooked-line data, generating migration artefacts (smiles) that significantly affect the quality of the migrated image. In contrast, the CRS-beam PSTM produces a high quality image where the smiles were attenuated. The application example reveals this new migration method as an alternative for pre-stack time migrating expressively crooked-line data. This method also can be applied successfully in straight-line data with irregular geometry, noisy and also with low fold. The CRS-beam PSTM also generates the common-image-gathers (CIG), usually with high signal-to-noise ratio.

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