Amsterdam '14

WS11-E02

From Zero-offset to Common-offset with Diffractions

B. Schwarz* (University of Hamburg), C. Vanelle (Institute of Geophysics, University of Hamburg) & D. Gajewski (Institute of Geophysics, University of Hamburg)

SUMMARY

The simulation of a zero-offset section leads to a first interpretable time image and is still one of the key processing steps. While recent works have indicated that common-offset stacking leads to improved resolution and illumination in complex settings, the zero-offset approximations are reasonably accurate, when lateral heterogeneity is moderate. Due to the increased dimensionality of the problem, the common-offset stack is computationally expensive, though. We suggest a hybrid scheme in which the zero-offset operators are locally refined by their common-offset counterparts. We show that for diffractions, the necessary connection between the attributes is achieved by simple geometrical reasoning. Synthetic examples indicate that due to the symmetry of raypaths, the zero-offset diffraction attributes can directly be used to perform a common-offset stack, promising a high potential for improved prestack separation and inversion.

Introduction

The 2D common reflection surface (CRS) stack is a multi-parameter extension of the classical CMP method. It was formulated for zero-offset (ZO, Jäger et al., 2001) and for an arbitrary common-offset (CO) central ray (Zhang et al., 2001). While the ZO approximation is fast and reasonably accurate for moderate lateral heterogeneity, the CO counterpart shows its strengths in complex settings, providing improved resolution and illumination at the cost of higher computational expenses (see, e.g., Spinner et al., 2012). In this work, we motivate a hybrid scheme in which we start with the less demanding ZO stack and use the results as a starting point for CO refinement. While in the reflection case attributes and traveltimes may be extrapolated, ZO and CO information is strongly coupled for diffractions (see, e.g., Berryhill, 1977), which we suggest to exploit in a straight forward decomposition principle. Application of this concept in a simple synthetic test reveals a good agreement of ZO-based prediction and the CO reference.

Diffraction symmetry and decomposition

In the ZO CRS stack (Jäger et al., 2001), the traveltime moveout around the central ray is approximated by a second-order expression. In 2D, the actual physical wavefront of a diffraction depends on the angle of emergence (α_0) and the local radius of curvature (R_{NIP}) of the NIP-wave (Hubral, 1983), which is fictitious for the reflection case (compare Figure 1(a)). The CO CRS stack by Zhang et al. (2001) generalizes this concept to arbitrary source receiver combinations and thus can characterize the full prestack data volume. Due to the general asymmetry of up- and downgoing raypaths it is parameterized by according attributes of two two-way wavefronts and a coupling coefficient, resulting in a higher dimensionality of the problem. For the diffraction case, however, the coupling between those two wavefronts vanishes and they reduce to one-way waves, resembling the NIP experiment in the common-shot (CS) and common-receiver (CR) gather, respectively (see Figure 1(a)). As a consequence, ZO and CO information is highly redundant for diffractions and ZO traveltime operators at a source ($\mathbf{x}_s$) and a receiver ($\mathbf{x}_g$) may be decomposed to CO operators,

$$t_{co}(\mathbf{x}_s,\mathbf{x}_g,t_0^{co},\alpha_s,\alpha_g,R_s,R_g) = \frac{t_{zo}(\mathbf{x}_s,t_0^{zo,s},\alpha_0^s,R_{NIP}^s) + t_{zo}(\mathbf{x}_g,t_0^{zo,g},\alpha_0^g,R_{NIP}^g)}{2} \quad , \tag{1}$$

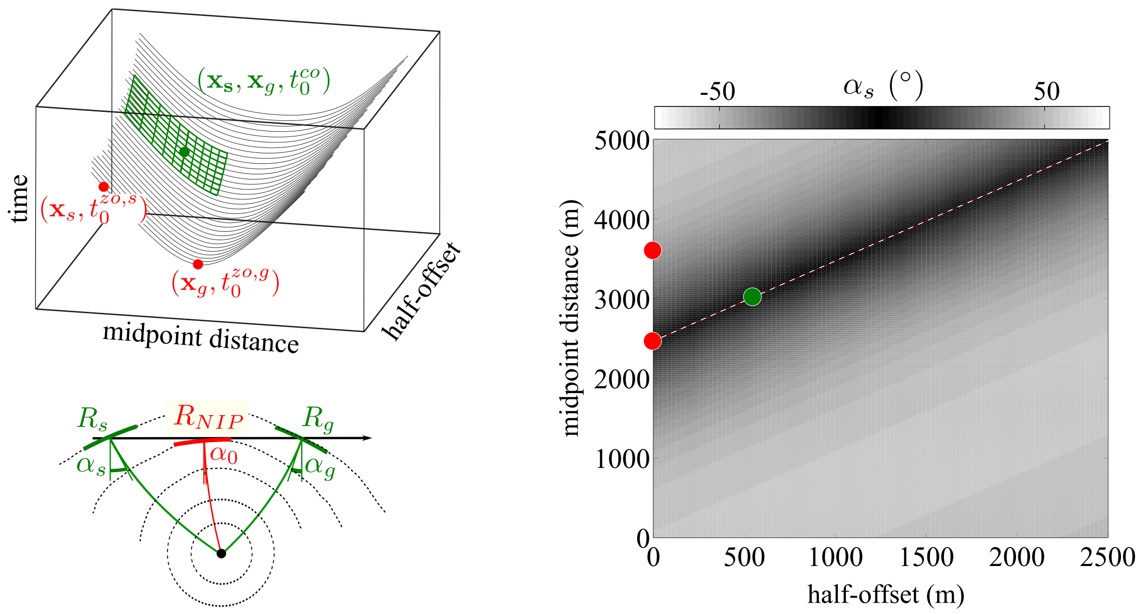
where t_0^i are the traveltimes of the respective reference rays and (α_s,R_s) and (α_g,R_g) represent the wavefront curvatures and angles of emergence of the CS and CR experiment respectively. In the following section, we test the potential of this decomposition approach for a simple heterogeneous model.

Synthetic test

Our synthetic example considers a diffractor in a constant vertical velocity gradient medium with $v =$ 2000 m/s+0.5 s^{-1} z, which allows for the forward-calculation of traveltime and attributes. The lateral position of the diffractor is at 2500 m. Figure 1(b) shows the analytic values of the emergence angle of the CR wave at the central source position and verifies that ZO and CO values are redundant and follow the trend of the CS configuration. Similar symmetries can be observed for the remaining attributes and the ZO traveltimes. In the second part of our synthetic test we apply the hyperbolic ZO CRS stack and the CO CRS stack to synthetic prestack data, generated for the same model. Observe in Table 1 that for the CO trace marked green in Figure 1(b), traveltimes and attributes coincide with remarkable accuracy, which lets us conclude that this decomposition can be utilized in common practice.

Conclusions

We suggested a hybrid scheme combinig the stability and efficiency of the ZO CRS stack with the increased illumination and resolution of the CO CRS method. While for reflection events the CO traveltimes and attributes may be extrapolated with the ZO operators, ZO and CO information turn out to be strongly coupled for diffractions. We presented a simple yet general decomposition principle that allows



(a) (b)

Figure 1 *(a) Illustration of the connection between ZO (red) and CO (green) information for the diffraction case. (b) CR wave emergence angle as a function of midpoint distance and half-offset. The coloured dots mark the ZO (red) and CO (green) locations that were considered in the synthetic test.*

	Prediction from ZO	CO	Deviation in %
t_0^{co}	1.0751 s	1.0727 s	0.2
α_s	0.0 °	0.0 °	0.0
α_g	37.5 °	39.7 °	5.5
R_s	1143 m	1120 m	2.0
R_g	1654 m	1608 m	2.9

Table 1 *Comparison of CO CRS traveltimes and attribute values with the corresponding ZO-based predictions.*

for an accurate prediction of CO attributes and traveltimes. A generic synthetic test revealed the strong redundancy of diffraction raypaths. Application to waveform data led to a very good agreement of ZO prediction and CO reference.

Acknowledgements

We thank the Applied Seismics Group Hamburg for continuous discussions. This work was partly supported by the sponsors of the Wave Inversion Technology (WIT) Consortium and the project ’Imaging steep structures with diffractions’ (BMU 0325363C).

References

Berryhill, J. [1977] Diffraction response for nonzero separation of source and receiver. *Geophysics*, **42**, 1158–1176.

Hubral, P. [1983] Computing true amplitude reflections in a laterally inhomogeneous earth. *Geophysics*, **48**, 1051–1062, doi:10.1190/1.1441528.

Jäger, R., Mann, J., Höcht, G. and Hubral, P. [2001] Common-reflection-surface stack: Image and attributes. *Geophysics*, **66**, 97–109, doi:10.1190/1.1444927.

Spinner, M., Tomas, C., Marchetti, P., Gallo, C. and Arfeen, S. [2012] Common-offset CRS for advanced imaging in complex geological settings. *SEG, Expanded Abstracts 2012*, doi:10.1190/segam2012–1099.1.

Zhang, Y., Bergler, S. and Hubral, P. [2001] Common-reflection-surface (CRS) stack for common offset. *Geophysical Prospecting*, **49**, 709–718, doi:10.1046/j.1365–2478.2001.00292.x.