Velocity model building using dense RMO picking for variable-depth streamer data

Fatiha Gamar-Sadat*, Robert Soubaras, Olivier Michot, Geoffroy Pignot (CGGVeritas), Amir Kabbej (Total)

Summary

The computation of velocity by tomography using Residual Move-Out (RMO) curves is widely used in the industry. The semblance-based, automatic dense picking of RMO has proved to be a very efficient technique for conventional data. However, in the case of variable-depth streamer acquisition, this technique is poorly adapted due to the presence of ghosts in the data. We present here a robust, automatic, high-order dense picking technique based on a cross-semblance criteria using the migrated and mirror-migrated common image gathers that eliminates the need for pre-stack deghosting prior to velocity update. This paper focuses on velocity model building using our method. It is applied to a complex 2D variable-depth streamer acquisition from Brunei, which is characterized by noisy data where faults and gas pockets coexist. We show that our method allows us to obtain an accurate velocity function conformable to structure that improves the focusing.
Introduction

In recent years, there has been tremendous progress in broadband seismic acquisition that allows the benefit of enhanced resolution and accuracy of imaging. For marine acquisition, Soubaras and Dowle (2010) proposed broadband acquisition involving a variable-depth streamer, a technique which has now been widely deployed (Lin et al., 2011). Whereas this solution presents an affordable way to record broadband signals, its processing has required a significant adaptation of the processing sequence (Rebert et al., 2012). Since an accurate deghosting cannot be done at an early step, it is performed through a joint deconvolution of a migration and a mirror migration (Soubaras, 2010). Several steps of the processing sequence have been already published: namely, multiple removal (Sablon et al., 2011) and 4D processing (Charrier et al., 2012). In this paper, we will address the complex issue of velocity model building (Depagne et al., 2012). For velocity model building, a critical need is the adaptation of Residual Move Out (RMO) picking to variable-depth streamer acquisition gathers strongly affected by ghosts. Unlike conventional data, the receiver ghost in variable-depth streamer data appears as a separate event with a different curvature from the primary event (Figure 1), significantly affecting the quality of RMO picked using conventional approaches (Siliqi et al., 2007). Several solutions are illustrated in Figure 1. The bottom path with the very accurate pre-stack dehosting of variable-depth streamer acquisition gathers was proposed by Soubaras (2010). Unfortunately this solution requires an accurate velocity model that is available only in the later steps of the imaging project. The top path shows a “raw” dehosting that just sums the primary and mirror gathers to produce a symmetrized gather. The quality of the resulting semblance panel shows the poor resolution we expected from such an approach. To improve the resolution, we propose a new high-density RMO picking tool based on cross-semblance criteria computed on migrated (normal migration) and mirror-migrated (migration of the mirror receivers) gathers. The solution is indicated in Figure 1 by the red arrow.

Figure 1: RMO picking of migrated and mirror-migrated gathers. The semblance panel corresponding to the dehosted gather (Soubaras, 2010) is shown on the bottom, while the semblance panel computed for the symmetrized gather is indicated on top. We propose an alternative solution based on a cross-semblance where the focusing of the semblance panel (center right) is greatly improved compared to the symmetrized gather and close to the dehosted gather.

We present below the cross-semblance criteria and velocity model building application used for a 2D variable-depth streamer acquisition dataset from Brunei.
RMO picking

There exists a great variety of high-density RMO picking tools. Let’s consider the one proposed by Siliqi et al., (2007) which has the characteristic of considering polynomial RMO curves:

\[ RMO(h) = C_2 h^2 + C_4 h^4 + C_6 h^6 + \ldots \]

where \( h \) is the offset (the vertical axis can be either time or depth). This tool is based on an automatic simultaneous picking of polynomial coefficients using orthogonal functions. The criteria for the picking is the semblance depending on the vertical axis, or time \( t \) (which is replaced by \( z \) for CIG depth gathers) and the RMO parameters \((C_2, C_4, \ldots)\)

\[ S(t, C_2, C_4, \ldots) = \left( \sum_{\text{offset}} CIG(t(h), h) \right)^2 \left/ \sum_{\text{offset}} (CIG(t(h), h))^2 \right., \quad \text{where} \quad t(h) = t(0) + RMO(h) \]

computed along RMO curves in offset over the common image gathers, \( CIG(t,h) \). \( \text{Noff} \) is the number of offsets.

To pick the common part of the migrated and mirror-migrated gathers for variable-depth streamer data processing, we propose to maximize the cross-semblance \( XS \) computed using the migrated and mirror-migrated gathers. The normal migrated and mirror-migrated gathers are named, respectively, the Up and Down gathers.

\[ XS(t, C_2, C_4, \ldots) = \sqrt{\left( \sum_{\text{offset}} CIG(t(h), h) \right) \left( \sum_{\text{offset}} CIG_{\text{mir}}(t(h), h) \right)} \sqrt{\left( \sum_{\text{offset}} (CIG(t(h), h))^2 \right) \left( \sum_{\text{offset}} (CIG_{\text{mir}}(t(h), h))^2 \right)} \]

The cross-semblance attenuates the artifacts due to ghosts, allowing accurate picking of the primaries.

The key elements of our algorithm are:
- a robust RMO picking based on a cross-semblance technique which allows the use of both migrated and mirror-migrated gathers (Figure 1)
- a high level of automatic editing of outliers. This tool chooses between several local maxima of the semblance and attempts to remove the interfered events
- a cleaning step that launches a selection process between consecutive reflection curves with the aim to remove those curves with a very different geometrical behavior compared to the neighborhood.

Our workflow contains the following stages:
- special pre-conditioning of data by applying denoise and demultiple (Sablon et al., 2011) tools
- high-density RMO joint picking on migrated and mirror-migrated gathers using cross-semblance criteria
- dip picking and skeleton creation on deghosted migrated stack (Soubaras, 2010)
- kinematic demigration (Guillaume et al., 2008) using the above information (i.e., RMO picks, dips, skeleton) to generate invariants to input to tomography
- non-linear slope tomographic inversion for velocity estimation
- re-migration with the updated velocity model.

Brunei 2D variable-depth streamer acquisition real data example

We have illustrated the capability of our proposed high-density/high-order cross-semblance RMO picking algorithm before pre-stack CIGs dehosting by applying the new methodology to a variable-depth streamer 2D dataset from Brunei. Dedicated denoising and SRME demultiple processes were
applied to the data prior to RMO picking to increase the signal-to-noise ratio (Sablon et al., 2011). Figure 2 shows that only the primary is picked as the red RMO curves follow the primaries rather than the ghost.

After dip and RMO picking, a first step of velocity model building was performed for time and depth using non-linear slope tomography (Guillaume et al., 2008; Depagne et al., 2012) as shown below (left image in Figure 4). A second step of velocity model building using high-definition tomography (Guillaume et al., 2012) resulted in an accurate high-resolution velocity model that conforms nicely to the structure (right in Figure 4). Up and Down gathers were migrated with the updated velocity model which produced CIGs with improved flattening (Figure 3). The final stack (Up) exhibits a noticeable improvement in resolution and continuity (Figure 5), especially on the shallow part of the data.

Conclusions

We have presented a robust, high-order joint (Up and Down) RMO picking method based on cross-semblance criteria, and we have demonstrated that this technique generates dense RMO picks without the need for pre-stack deghosting. Using data acquired offshore Brunei, we have shown that the use of dense joint RMO picking on variable-depth streamer acquisition CIGs for migration velocity analysis yields an improved velocity model update which follows geologic structures.
Acknowledgements

We thank CGGVeritas, TOTAL E&P DEEP OFFSHORE BORNEO, the CA1 Joint Venture and Petroleum BRUNEI for permission to present this work.

References

- Charrier, P., 2012. 4D Processing Between Variable Depth and Conventional Streamer Data, 74th EAGE Conference & Exhibition.

Figure 5: Final stack (Up data). Comparison between migration using the initial velocity model and final Tomo HD velocity model updated using the new picking based on cross-semblance between migrated and mirror-migrated gathers.