Robust Residual Gather Flattening

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Summary

We present a robust residual gather flattening technique based on trace correlations, which time-aligns coherent events across offsets or angles. We show how gathers to which we apply this method following migration and residual moveout corrections yield more coherent stacks, cleaner AVO results as well as more reliable velocity estimates.

Introduction

Well-aligned or "flat" events are key for high quality amplitude versus offset or amplitude versus angle fitting. In the context of marine 3D and 4D processing we have recently reported (MacKenzie et. al, 2004) on our efforts to improve gather quality with automated dense higher order moveout correction (including improved filtering methods). Here, we show how residual non-flatness of the data that cannot be further improved with the velocity picking tools, can nevertheless be corrected for prior to AVO. This gather pre-conditioning can be applied in a time-variant manner and is therefore able to correct for conflicting time-shifts. We also show that polarity reversal events are correctly flattened.

Method

The flattening technique is based on relative cross-correlations between traces in a gather and a pilot trace. The choice of pilot trace is driven by signal to noise considerations and is generally chosen to be a partial stack of near-to-mid offset traces.
Key elements of our algorithm are:

- A robust correlation technique which calculates time-shifts as a function of offset/angle and two-way time.
- The use of the absolute maximum of cross-correlation in order to preserve polarity reversals.
- Automatic editing of outliers and filtering of time-shifts within and across gathers.

Our method then consists of:

- Higher order RMO after migration.
- A two-pass residual gather flattening using a long-window (200 ms) followed by a short-gated window (wavelength driven, but typically 40-60 ms).
- A user defined pilot trace generally chosen as a partial stack of near-to-mid traces.

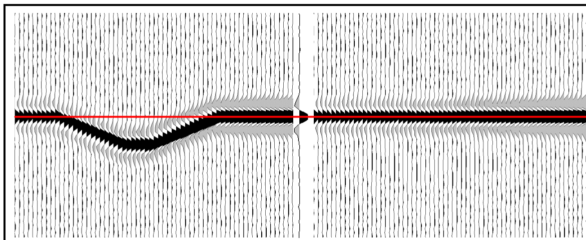

Figure 1: Simplest application of gather flattening: one event with a wobble and random noise (left) is aligned (right) to the pilot trace (middle).

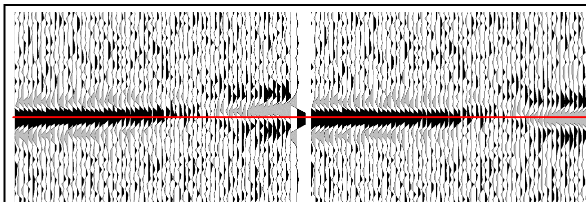

Figure 2: An event with an amplitude change and a polarity reversal (left), with added noise, is correctly flattened (right figure) to the pilot trace (middle) by the algorithm.

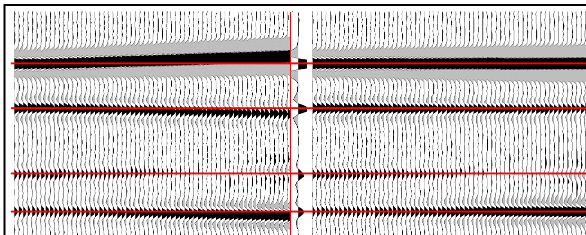

Figure 3: An event with an amplitude change and a polarity reversal (left), with added noise, is correctly flattened (right figure) to the pilot trace (middle) by the algorithm using a cascaded approach (long correlation window followed by a short one).

Synthetic Examples

We start by showing three synthetic examples which highlight the robustness and limitations of the method. Figure 1 shows a single event (with added white noise) with a "wobbly" event. For correct alignment the choice of pilot trace is clearly key. For example, if the pilot is chosen as the full stack, the event will still be flattened but shifted to a slightly later time than that of the near traces.
Figure 2 shows that our algorithm preserves polarity reversals. Here, estimating spatially consistent time-shifts across the gather is key as this downplays events at the

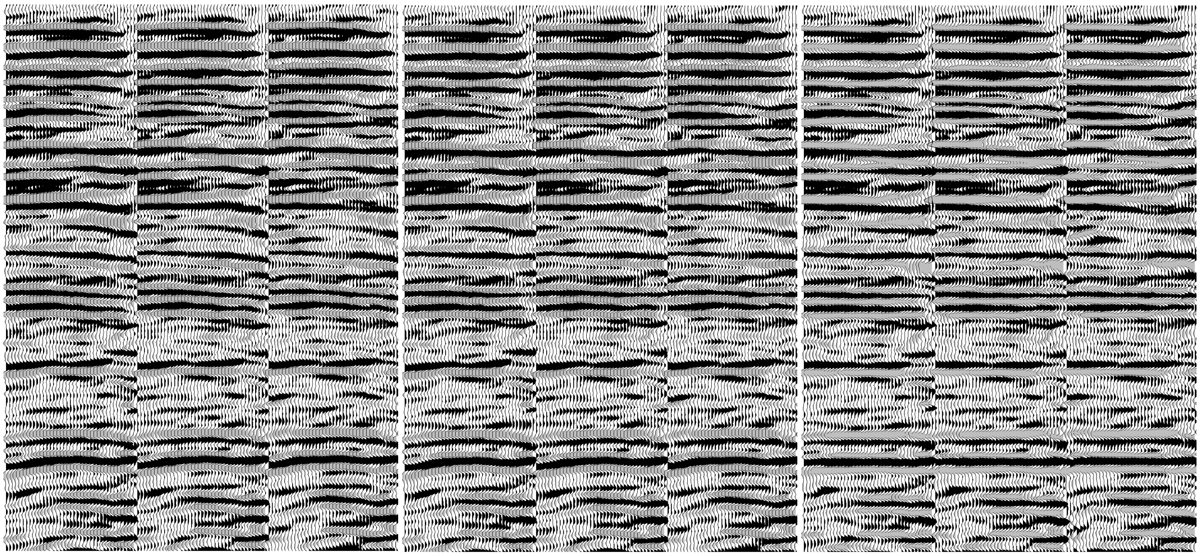

Figure 4: Three adjacent gathers after migration (left), after RMO (middle) and after RMO and residual cascaded flattening (right). Gather flatness has significantly improved at all offsets and the data is now more consistent with an AVO model.

locus of the polarity reversal where the signal to noise is poor.

Figure 3 shows a synthetic with a combination of events with conflicting time-shifts and different AVO effects, including one polarity reversal. Here, we apply a cascaded approach using first a long time-window (200 ms) followed by a shorter cross-correlation analysis (60 ms) which is able to resolve the conflicting shifts necessary to align events. The cascaded technique is our preferred approach: we generally find it to give superior results to a one-pass short window method. In the following section we shall demonstrate this on real data.

North Sea Data Examples

The necessity to have flat events in order to obtain reliable gradients has been well documented in the AVO literature (e.g. Hinkley et. al, 2004). Following pre-stack time-migration we perform higher order residual moveout. This removes a fair amount of non-flat events at the far offsets and updates the velocities accordingly. Figure 4 (left and middle) shows the results on gathers from North Sea data whereas figure 5 (left and middle) compares the migration velocities to the updated velocities after RMO. We see that some gathers suffer from residual non-flatness after RMO, particularly at small offsets. The right-hand plot of figure 4 shows that these gathers are well flattened on both the nears and the fars if we run the cascaded residual flattening following the RMO. If we now apply reverse NMO on the corrected gathers we can rerun the velocity analysis on the coherency-enhanced data. Figure 5 (right) shows the result of this analysis. In figure 6 we plot two of our velocity QCs, the semblance and the velocity “skeleton”, showing the spatial continuity of picks with high semblance. Both QCs show that the residual flattening significantly increases the reliability as well as the spatial continuity of the velocities. Figures 7 and 8 show the value of using a cascaded approach with a long correlation window followed by a short one. The second short-pass window (figures 7 and 8, right) yields a marked improvement in residual RMO and stack continuity compared to the first pass (figures 7 and 8, middle). We find that the two passes are more stable than a single short-window application. Finally, in figure 9, we compare intercepts and gradients with and without residual gather flattening. Whereas intercepts are more coherent, a significant amount of residual energy has been removed on the gradients.

Conclusions

We have presented a robust gather flattening algorithm based on cross-correlations and we have demonstrated that this technique preserves polarity reversal events. Using North Sea data, we have shown that the application of residual gather flattening after migration and RMO yields improved data continuity, better velocity picking and reduced gradient noise.

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Figure 5: Velocities for the migration (left), after RMO (middle) and after RMO followed by residual cascaded flattening (right).

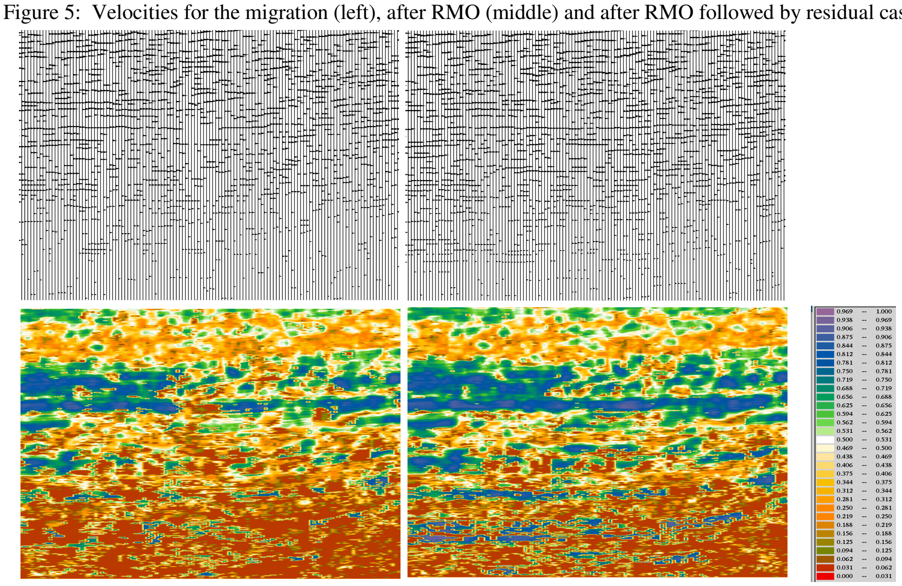

Figure 6: Top row: Velocity skeletons without (left) and with (right) residual gather flattening. The continuity of events is significantly increased. Bottom row: Velocity picking semblance without (left) and with (right) residual gather flattening. The semblance is significantly increased showing that the velocities are now picked with higher confidence.

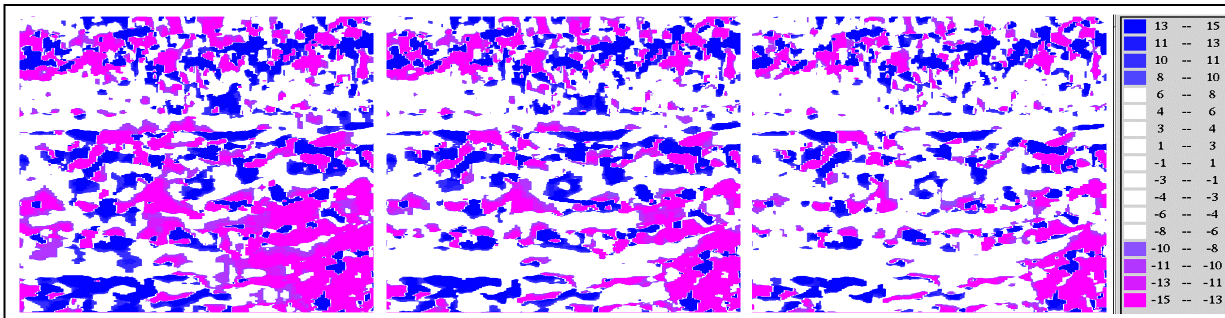

Figure 7: Initial RMO (left, in ms), RMO after first-pass (long window) flattening (middle), RMO after two-pass approach (right). There is significant uplift from the second pass, which uses a short window correlation length (60 ms).

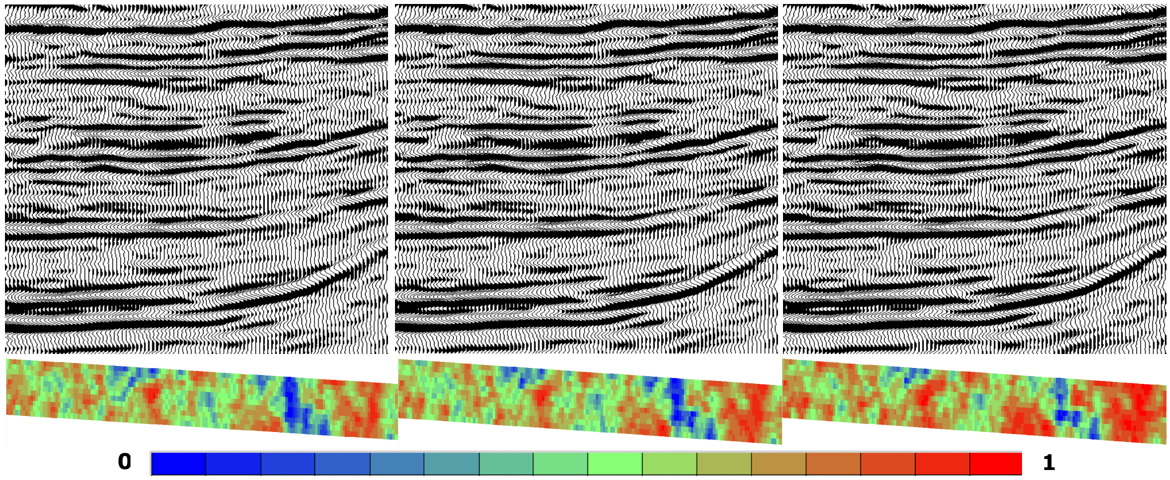

Figure 8: Stack data: input (top left), after RMO and long-window gather flattening (top middle), after RMO and cascaded flattening (top right). The continuity of events is best when using the cascaded approach. The corresponding correlation maps (bottom) of near and far stacks show the improvement achieved after each step.

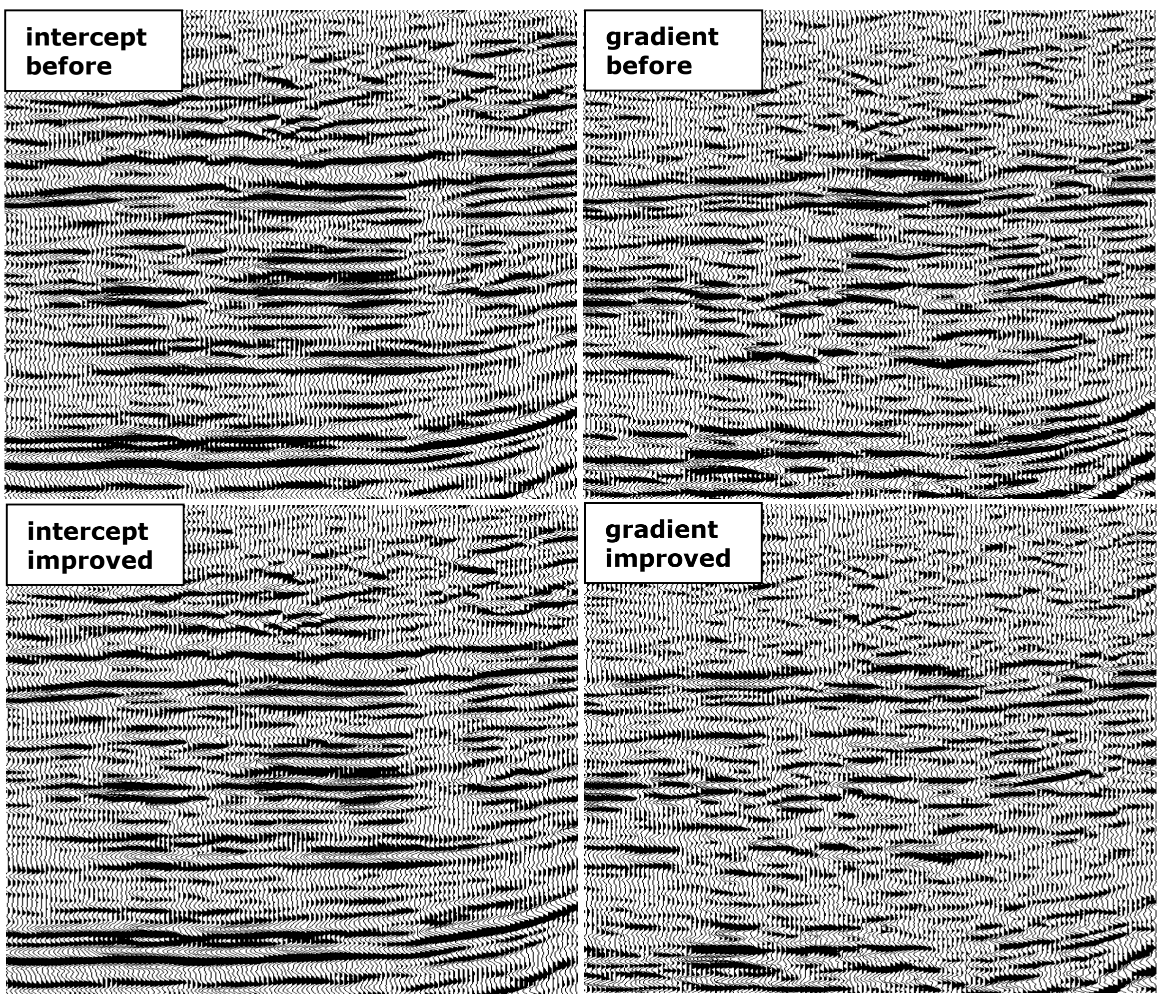

Figure 9: Intercepts (left) and gradients (right) after RMO (top) and with RMO plus cascaded gather flattening (bottom). Interecepts are more continuous whereas significant amounts of residual energy are removed on the gradients after residual flattening.