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A Case Study of Simultaneous Data Separation with Enhanced Adaptive Subtraction Method: Offshore West of Shetland

Z. Liu (TGS), B. Wang (TGS), J. Langhammer* (TGS), J. Specht (TGS), C. Egger (TGS) & Y. Zhai (TGS)

SUMMARY

We acquired 2D steamer simultaneous source surveys recently at offshore west of Shetland Island. This acquisition configured a sequence of dual sources and a sequence of triple sources in dithering shooting scheme. A case study investigated the capability of an enhanced adaptive subtraction (EAS) method for deblending the real simultaneous streamer data. The results demonstrated that the EAS method can achieve high quality deblending results on both dual source and triple source data. The weak events and complex subsurface structures are preserved very well, and the energy leakages are very little. The main frequency content and frequency notches are also preserved for the broadband data. Furthermore, the SPI test and runtime analysis showed that EAS is not only effective but also efficient so that it can be used as a QC tool during acquisition.

Introduction

In recent years, more and more oil and service companies have studied simultaneous shooting for marine acquisition. Compared to conventional marine seismic acquisition, simultaneous shooting can either reduce the acquisition costs by reducing the temporal shot intervals, or increase the data quality by increasing the number of shots in the same acquisition time. Alternatively, simultaneous shooting can further advance our data acquisition by allowing the combination of these benefits.

The processing of the simultaneous source data can be similar to conventionally acquired data, but it introduces crosstalk artefacts to the migration image from incongruous sources, thus decreasing imaging quality. Many different data separation techniques exist which attempt to separate data while minimizing source interference. These approaches can be grouped into two main categories: passive separation and active separation. Our approach is a hybrid.

Active separation methods solve the data deblending as an inversion problem (Moore et al., 2008; Abma et al., 2010). First, we transform the simultaneous source data to a sparse model domain, so events from different shots are better separated, thus assisting deblended data reconstruction.

Passive approaches usually start from the pseudo-deblended data and sort the result into another domain where the blending noise becomes incoherent. These approaches remove noise either by coherency filters (Beasley et al., 1998, Huo et al., 2012), or by iterative subtraction (Mahdad et al., 2011, Peng et al., 2013).

We at TGS (Kim et al., 2009) have developed adaptive subtraction flows to separate simultaneous sources for OBC data. While, it is effective in attenuating the interference in the data and preserving weak signal, it also, can degrade separation when simultaneous source distance is small. The simulation tests show shot distance should be greater than 2 km.

This passive method has been improved on dual source simultaneous data by subtracting the incoherent noise and adding the residual back to the data through an iterative approach (Liu, et al., 2014). Since we can separate stronger signals at the earlier iterations, operating on weaker events at the later iterations, it is not necessary for the simultaneous sources to be far apart. Simulated synthetic data tests show that this enhanced adaptive subtraction (EAS) method can deblend data with two simultaneous sources as close as to 25 m.

Later in 2014, TGS acquired 2D real streamer surveys of simultaneous sources at west Shetland Island area. We expand the EAS method and apply it on these data sets to obtain high quality deblended data.

Acquisition Configuration

We acquired several different simultaneous shooting sequences, along with a conventional shooting sequence as the reference (See Figure 1a). Here we test EAS workflows on SEQ 109 and SEQ 112. SEQ 069 is a conventional flip-flop shooting survey (Langhammer et al., 2015).

SEQ 109 is a dual simultaneous source data with 3480 cubic inch volume sources separated by 50 m (Figure 1b). Shotpoint interval (SPI) is 12.5 m and the dithering time delay is in +/-250 ms range. The streamers are 12.6 km long slanted cables with streamer depth from 12 m (near) to 30 m (far).

SEQ 112 is a triple source simultaneous survey (Figure 1c), with all three sources possessing different volumes. The side two sources are 2495 cubic inches, and the center one is 1970 cubic inches. Different triple-source volumes were logistical, and due to different volumes of the initial sub-arrays for the dual-source setup. Time did not permit mechanical changes. Source separation is 25 m, and the shotpoint interval is 12.5 m. Source dithering time is +/-300 ms, while the streamers design matches SEQ 109.

These surveys have several features which are different from the data we processed before:

- This is the first time we apply EAS work flows on real streamer simultaneous data
- The streamers are slanted cables
- The source wavelet is frequency broadband
- SEQ112 has triple sources with two different volumes
- Some areas have relative complex subsurface geological structures

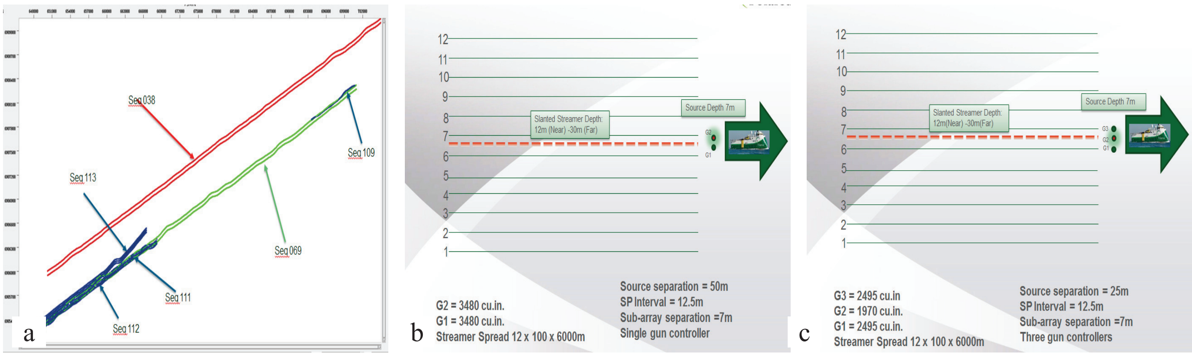

Figure 1 *(a) Survey area of offshore west Shetland project. We focused on dual-source dithering shooting data SEQ109 and triple-source dithering shooting data SEQ 112. SEQ 069 is the reference data with conventional flip-flop shooting; (b) Acquisition configuration for SEQ 109; (c) Acquisition configuration for SEQ 112.*

Field Data Processing and Results

Our previous work demonstrated that the EAS method is successful on OBC/OBN data and synthetic streamer data (Liu, et al., 2014). Compared to OBN/OBC data or synthetic streamer data, the receiver location of real streamer data varies in common channel domain. It is possible for this factor to degrade the deblended quality, but the EAS method can handle this problem by adaptive subtraction and an iterative update. Since all the procedures are processed in common channel domain, the streamer depth variation is not an issue for the EAS method.

Simultaneous source separation quality usually depends on many factors. Shotpoint interval (SPI) is one of most important parameters. The SPIs for SEQ109 and SEQ112 are 12.5 m, which is beneficial to achieve quality deblending. We resampled SEQ 109 data to 25 m, and 50 m SPI, to test the tolerance of the EAS approach. Notably, deblending quality is also dependent on the subsurface geological structures. Using the EAS method we are able to separate this blended survey data, preserving weak events with very little leakage. Finally, the source wavelet contributes as a factor, affecting deblending quality. Although, high frequency content is more likely to be damaged because of lower coherency in the common channel domain during the process. Ultimately, the field data tests show that EAS maintains frequency content and notches, even for broadband data. This enables normal deghosting and broadband processing procedures on the deblended data.

To allow the EAS workflows to be applied to SEQ 112 data, we also expand the approach to separate the data for more than two simultaneous sources. The results demonstrate that the EAS is effective for triple source separation, and also robust to airguns with different volume.

Figures 2a and 2c show the common offset gather of primary source and secondary source data with their own time alignment respectively. We can see that the interference noise is very strong, the complex structures and the weak events have lost continuity because of the contamination of noise from the other source. After deblending (shown in Figures 2b and 2d), most of the interference noise is eliminated, the dipping and complex structures have not been damaged at all, the weak events are preserved very well, and the continuity is also improved.

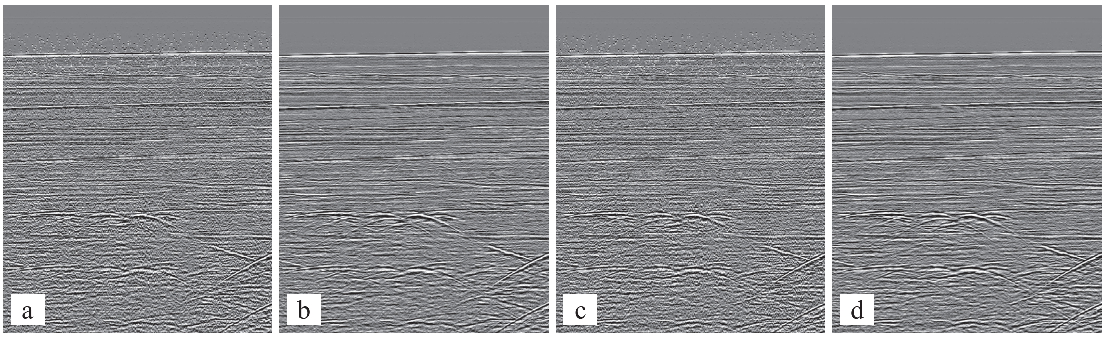

Figure 2 *Common-channel gather for near channel of SEQ 109: (a) Primary source before deblending; (b) Primary source after deblending; (c) Secondary source before deblending; (d) Secondary source after deblending.*

Figures 3a, 3b and 3c show the NMO stack sections of the SEQ 109 data before and after deblending, and the reference line SEQ 069 respectively. Before deblending, there are strong crosstalk artefacts, especially in the shallow section. After deblending, those artefacts are eliminated, and the complex structures and dipping events are preserved very well compared to the reference data SEQ 069.

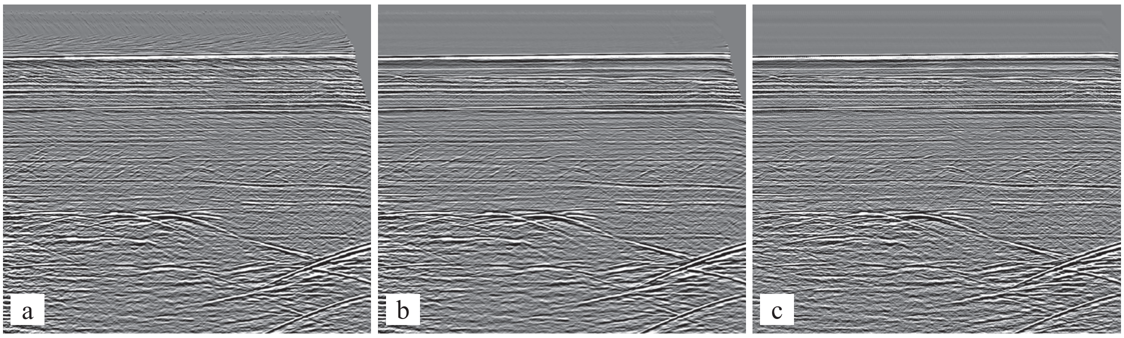

Figure 3 *NMO stack sections: (a) Simultaneous data SEQ 109 without deblending; (b) SEQ 109 after deblending with EAS approach; (c) reference SEQ 069 with conventional flip-flop shooting.*

We also apply EAS on resampled data with 25 m SPI and 50 m SPI. Figures 4a and 4b show the primary source data of blended input and deblended result with 12.5 m SPI respectively. Figures 4c and 4d show the deblended primary source for resampled data with 25 m SPI and 50 m SPI respectively. The results are still acceptable except there is more residual interference noise around the complex structures in the deep section.

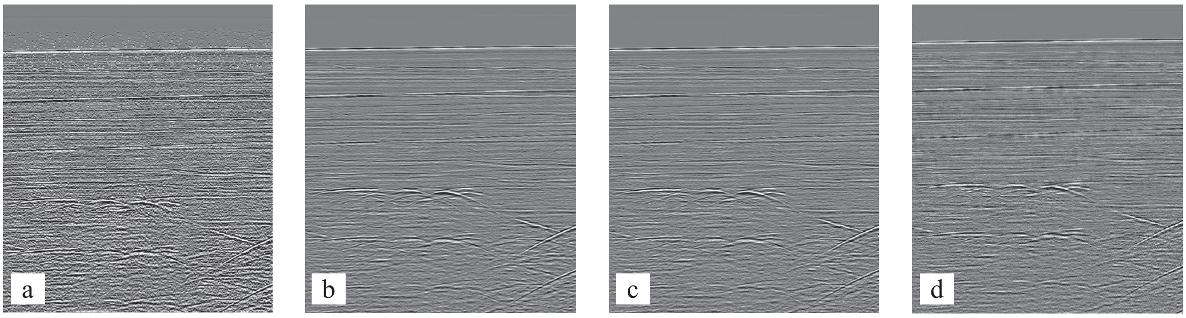

Figure 4 *A common-offset gather for near channel of SEQ 109: (a) before deblending; (b) after deblending, SPI=12.5 m; (c) after deblending, SPI=25 m; (d) after deblending, SPI=50 m.*

We apply the EAS work flows to obtain well-separated data for the three-source survey SEQ 112 shown in Figures 5a through 5d. The results demonstrate that the EAS approach can work for the simultaneously acquired data with more than two sources, and it is robust for different types of airguns. The spectrum plots in Figure 5e show that the main frequency contents and notches are preserved.

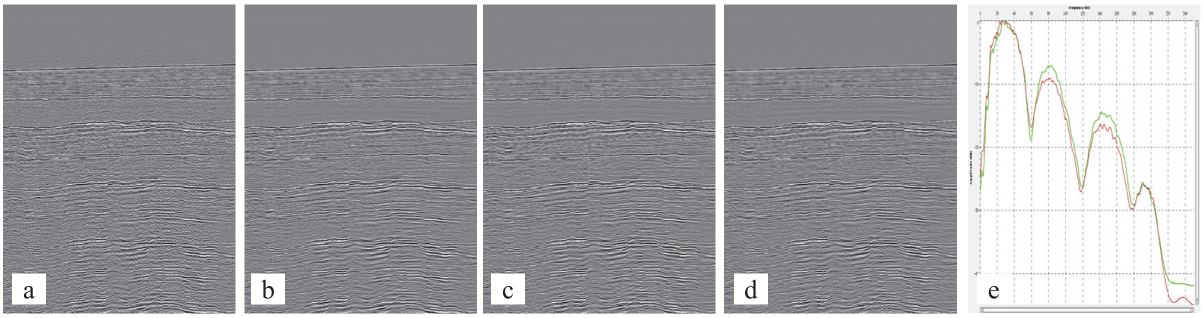

Figure 5 *Deblending results for triple source data SEQ 112 with EAS approach: (a) before deblending; (b) source 1 after deblending; (c) source 2 after deblending; (d) source 3 after deblending. (e) Spectrum of blended data (green) and source 1 data after deblending (red).*

Finally, the EAS method is very efficient. It can finish 5 to 6 iterations (which are usually good enough) for a common-channel gather of data in less than one minute on a single CPU machine. So we can use it as an onsite QC tool during acquisition.

Conclusions

We have applied EAS on real field-acquired simultaneous-source data at west Shetland Island area. The deblending quality is the best when SPI is 12.5 m, but it is also acceptable when SPI is as large as 50 m. The reconstructed deblending data and the NMO stack sections demonstrate this new technique is quite effective even for relatively weak events and complex structures. The frequency content is well preserved even for broadband data so that we can apply broadband processing on the deblended data. It is also flexible for simultaneous data with more than two sources, and is robust for different types of airgun. Finally, this EAS method is very efficient so that it can be used as a QC tool during acquisition.

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