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Iterative Deblending of OBN Data

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SUMMARY

Blended acquisition of ocean bottom node (OBN) surveys may provide important time savings when the survey duration is tightly constrained. We present a method that focuses on the deblending of OBN data recording two simultaneous sources in the Gulf of Mexico. By knowing the respective shot time interval and shot location of two or more sources in the continuous recording data, we can extract the common receiver gathers of each source and deblend them using an iterative coherency-enhancement and subtraction method. In this method, the initial energy model is estimated in the Tau-P domain, and the noise model is estimated adaptively in the curvelet domain. Results show little signal leakage after three iterations of separation.

Introduction

The distinguishing characteristic of simultaneous-source acquisitions is the temporal overlap of shot records. Hence, the shot time interval for this type of survey is reduced when compared to the equivalent non-simultaneous source survey. This reduction in the shot time interval improves the acquisition's efficiency to allow denser shot sampling, longer record length, reduced survey duration and therefore potential cost savings (Berkhout *et al*. 2013; Moore 2013). For these reasons, simultaneous-source acquisitions have been used on land for many years. Recently, a few applications of simultaneous sources to ocean bottom cable (OBC) acquisition have demonstrated the high production efficiency (Abma *et al*. 2013, Hays *et al*. 2014). In ocean bottom node (OBN) acquisition, however, node deployment and retrieval time is a large portion of the whole project and consequently the shot efficiency gain is not as significant as in OBC acquisition, but could still provide important time saving when the survey duration is tightly constrained.

Simultaneous-source acquisition with airguns commonly uses dithering and/or independent source methods (Moore *et al*. 2008; Abma *et al*. 2013). The objective of these two methods is to create enough randomness in the shots to facilitate the shot separation in the deblending step. In the dithering approach, a small random time shift is usually added to one of the sources while keeping the regular time interval for the other source. In independent simultaneous sources, the randomness is created by shooting the two sources independently (i.e., each source has its own shot time interval and pattern of shooting). In this type of acquisition, the effective time shift between the sources can be large, and the stronger interfering energy is uniformly distributed in time along the shot record.

Simultaneous-source data can be separated using either passive or active methods. In the passive method, the simultaneous shots (referred to as blended shots because their wavefields blend together) are simply migrated without any explicit shot separation. Using a migration domain in which the crosstalk noise from simultaneous sources is incoherent, the migration operator can attenuate the incoherent noise and keep the coherent energy. In the active method, the blended shots are separated before migration, a process referred to as deblending. Most active deblending methods use a sparse representation of the seismic data. This can be formulated as an inversion problem (Abma *et al*. 2010; Moore *et al*. 2008) or as iterative random noise attenuation (Mahdad *et al*. 2012). Our deblending method belongs to the iterative random noise attenuation group. In our case, the noise model was improved by estimating it adaptively in the curvelet domain and in alternating time configurations as the iterations move forward.

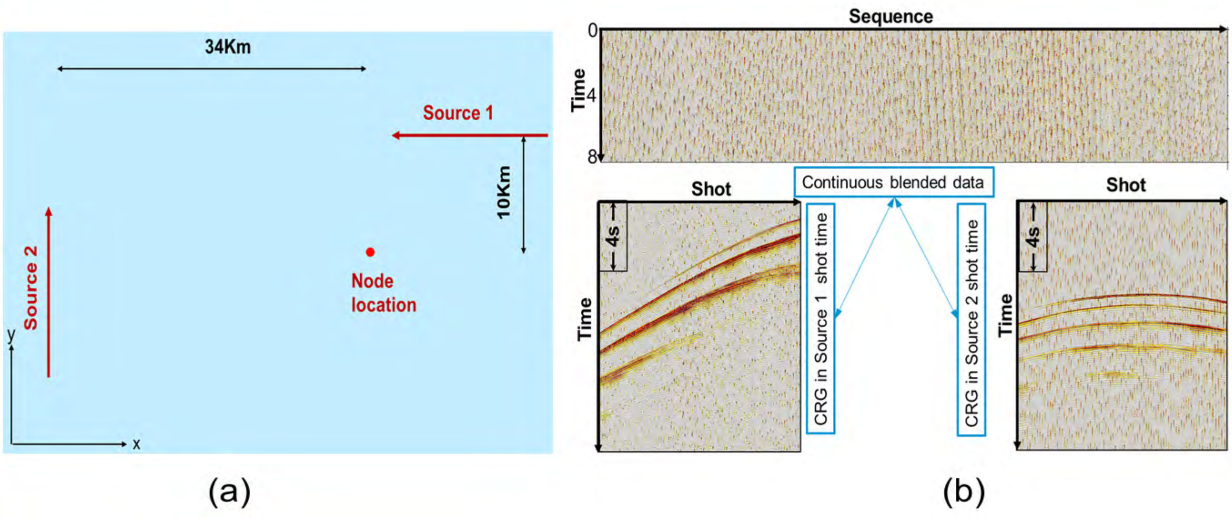

Figure 1 *(a) Shot locations for the OBN blended acquisition. The red arrows indicate the shooting direction of both sources. (b) Continuous blended data for one shot line. Top: The continuous record. Bottom left: Common receiver gather (CRG) formed with data aligned by Source 1 shot times. Bottom right: Data aligned by Source 2 shot time.*

Method

We used a blended OBN data example from the Gulf of Mexico. Two independent sources were deployed in perpendicular directions (Figure 1a). The shot spacing was 40 m in the x direction (Source 1) and 37.5 m in the y direction (Source 2) giving shot time intervals of 16 and 13.5 seconds, respectively. The shots from these two sources were recorded continuously by the same OBN. In Figure 1b, the continuous record is plotted in 8-second intervals. In this continuous record, all energy was incoherent because neither of the two sources were aligned by their acquisition times. In the two lower images of Figure 1b the continuous-time data is aligned by the acquisition times of Source 1 and Source 2, respectively. In these common receiver gathers (CRG) the energy from the one source was coherent, while the energy from the other source was incoherent because of the randomization of one source acquisition times relative to the other.

For blended acquisitions, the continuously recorded data contains energy from all shots from all sources (where the number of sources determines the number of blended shots) in addition to background noise (not related to the known sources). In our method, all shot times are known. As a result, we can extract each shot from the continuous data and create a CRG for each source by temporally aligning segments of the continuous record relating to shot times from any of the sources.

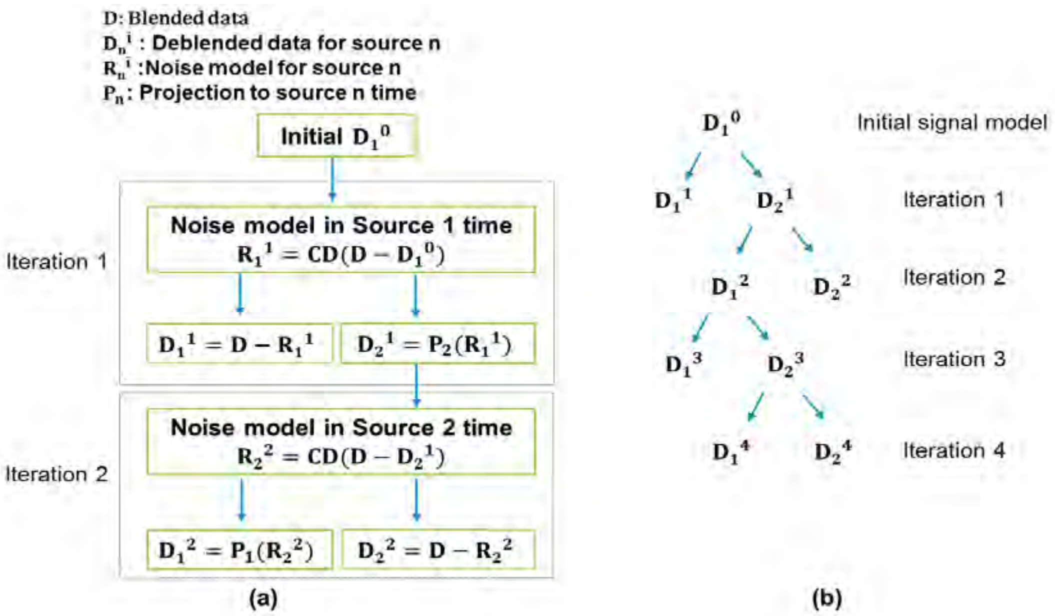

Figure 2 *(a) Deblending flow for the first two iterations. CD stands for adaptive subtraction in the curvelet domain, the subscripts represent the source number, and the superscripts represent the iteration. (b) Deblending flow diagram for additional iterations.*

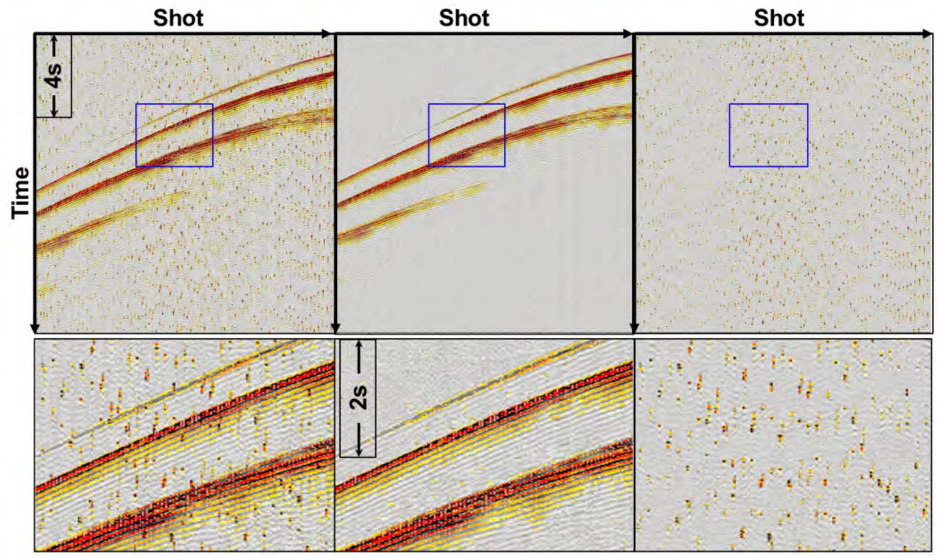

Figure 3 *Deblending of Source 1. Top left: Initial blended CRG. Top center: reconstructed CRG at the third iteration. Top right: Difference between the blended and the reconstructed CRG (at third iteration). The bottom figures are the corresponding zoom areas of the blue windows.*

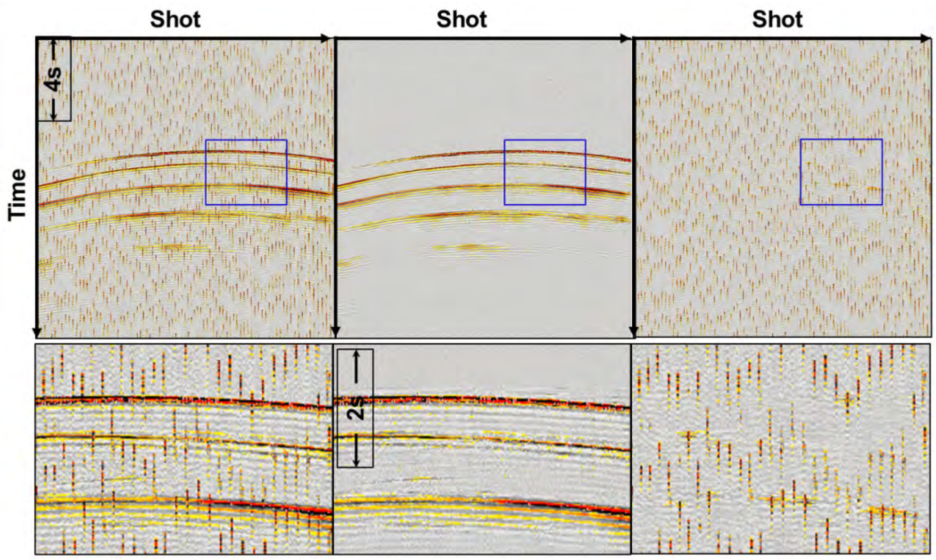

Figure 4 *Deblending of Source 2. Top left: Initial blended CRG. Top center: Reconstructed CRG at the third iteration. Top right: Difference between the blended and the reconstructed CRG (at the third iteration).The bottom figures are the corresponging zoom areas of the blue windows.*

The first two iterations of the deblending workflow are shown in Figure 2a. This method starts with an initial deblended model (signal model) for Source 1 (D_1^0). A coherence-preferred anti-leakage Tau-P inversion method (Peng 2014) is used to estimate this initial model. Then, the noise model is estimated adaptively in Source 1 acquisition time and used to reconstruct the deblended data for both sources as can be seen in Figure 2a. For the second iteration, the noise model is estimated in Source 2's acquisition time, and the deblended data for this iteration are estimated similarly to Iteration 1 (Figure 2a). This process continues for more iterations (Figure 2b) until the leakage energy is no longer reduced. In this flow, the noise model is estimated in alternating time domains. This improves the noise model until convergence is reached. In the same fashion, as the noise model is improved, the interference noise (leakage energy) is reduced.

The deblending flow relies on the method used to estimate the initial signal model for Source 1 and the curvelet domain adaptive subtraction used to estimate the noise model at every iteration. The coherence-preferred anti-leakage Tau-P inversion method is robust and can attenuate incoherent noise energy. The efficiency of the anti-leakage Tau-P method appears to speed up convergence of the deblending flow. Also, the curvelet-domain adaptive subtraction used in the noise model estimation provides better results compared to adaptive subtraction in the time domain (Wu *et al*. 2013).

Results

The deblending flow (Figure 2b) was used to separate the blended OBN data (Figure 1b). After the third iteration of separation for Source 1, no visible coherent energy was observed in the removed energy (Figure 3), suggesting that the separation flow works effectively with just a few iterations. Figure 4 shows the deblending results for Source 2. Slight signal leakage can be observed on this difference, attributable to the relatively low signal-to-noise ratio of Source 2 caused by the large distance from the receiver (Source 2 shot is in the range 34 km to 36 km of offset).

Conclusions

We presented a method to separate simuletaneous-source OBN data using an active, iterative coherency-enhancement and subtraction technique that converges in just a few iterations. Examples using real blended OBN data demonstrate that this method effectively separates the blended sources in three iterations with minimal signal leakage.

The deblending method used in this work can be easily extended when more sources are available. Future work should consider the sensitivity to different source separations and to test the applicability of the method to towed-streamer simultaneous-source data.

Acknowledgements

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