Record-length extension by rank-reduction de-blending

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SUMMARY

Would you throw away data just because it was not intentionally recorded?
This is often the case when dealing with continuous recording systems, where prior to processing the data is divided up into shot records which exclude the overlap from the next shot. The resulting decrease in record length can be detrimental to the imaging of deep targets. The goal of this paper is to demonstrate a method to recover signal present in the overlap zone. The proposed method is based on a robust-rank reduction 3D filter applied cable-by-cable across a range of shot points and channels. The results are encouraging and show that signal recovery is feasible even in this unusual blending scenario characterized by extreme amplitude differences between blended signals.

Introduction

In recent years, continuous recording has become increasingly popular for marine acquisition. Trace length is no longer an acquisition parameter but a processing choice: the dataset is recorded without interruption and is arranged into shot records after the acquisition. If the trace length is longer than the firing-time gap, the overlap of the following shot will hide the deep part of the shot record; in other words, in the deep part of the shot record, the two sources are blended. Can we then successfully de-blend the signal present in the overlap zone?

Several de-blending techniques have been developed over the past few years (Berkhout 2008, Mahdad et al. 2011, Maraschini et al. 2012, Wason et al. 2014, Cheng and Sacchi 2015, Kumar et al. 2015), but most of them are customized to separate almost simultaneous sources, aiming for signal preservation. In this paper we focus on the case where the blending noise amplitude is orders of magnitude higher than the signal, aiming to retrieve as much signal as possible whilst removing all of the blending noise.

De-blending strategy

The proposed method can be used to process a continuous recording dataset, with sources fired at given locations. TL1 is the minimum firing time gap, TL2 is the chosen trace length that allows signal overlap (see Figure 3 for symbol explanation). As the source is fired at predetermined locations, the firing time gaps vary from shot to shot due to the natural variability of the boat speed, resulting in randomness of the overlapping shot in the common channel domain.

When the sources are fired almost simultaneously, a "symmetric" approach, which gradually reconstructs the sources, can be used for the separation. This approach is not suitable in the considered scenario, where the signal to blending noise ratio is very small. For this reason we suggest to first reduce the amplitude of the blending noise S2, and then estimate the signal S1 using a rank reduction filter.
The scheme of the method is described in Fig 1:

Step 1 - Preliminary filters (e.g. swell noise attenuation, low cut) are optionally applied before the deblending process. De-ghosting and de-signature can be applied before or after the deblending. Additional preliminary filters can be applied to remove, from the overlap area, energy that cannot be primary (high frequency, steep events).

Step 2 - After removing time delays between S1 and S2 (to make S2 coherent), a 3D rank reduction filter (Maraschini et al. 2012, Cheng and Sacchi 2015 and Kumar et al. 2015) is applied to estimate S2. This estimation is then removed from the blended dataset.

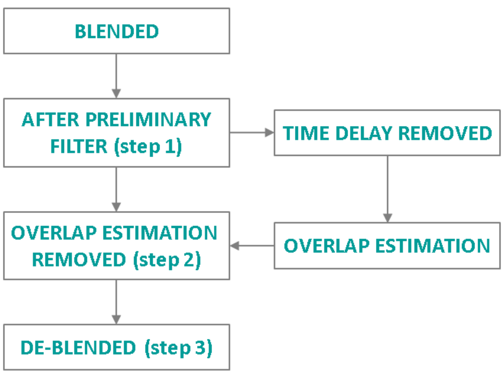


Figure 1 *Algorithm*

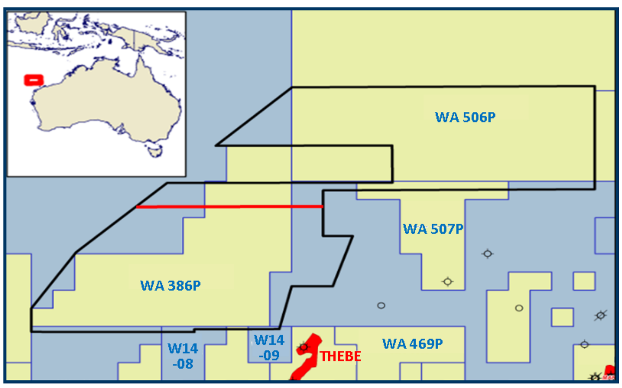


Figure 2 *Survey Map: the red line identifies the location of sequences A and B*

Step 3 - After adding back the time delays, a robust 3D rank reduction filter (i.e. Trickett 2003 and Trickett et al. 2012) is applied in common channel domain to remove the residual blending noise from S1.

At step 3, a robust rank reduction filter is preferred over a standard one, as it is better suited to handle the erratic interference noise that remains after step 2, which does not even approximately fit a stationary Gaussian statistical distribution. Erratic noise is handled by the introduction of iterations, and therefore its handling determines an increase in computational cost. At step 2 the main objective is the extraction of the S2 signal, and this can be achieved without iterations because the signal to blended-noise ratio is high.

Carnarvon basin acquisition

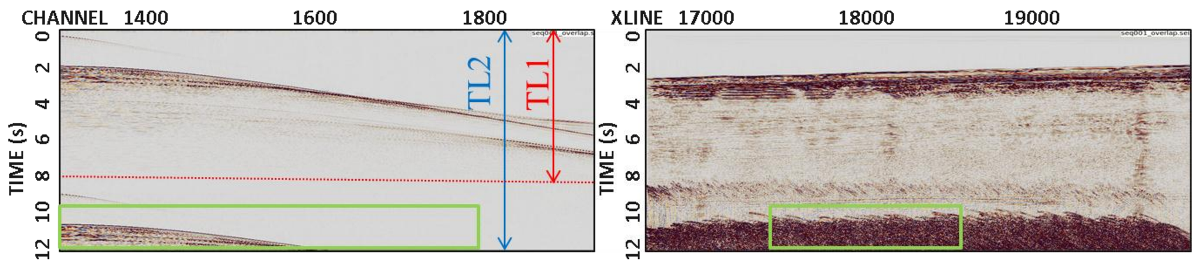
Dolphin Geophysical, in collaboration with project partner TGS, acquired a 3D survey on the Exmouth Plateau, offshore Western Australia (Figure 2). This survey provides ca 13,415 km^2 of new 3D coverage over this frontier area. In order to provide good imaging throughout the thick Triassic section and down to the deep Permian marker, which is at 9.0 - 9.5s in some areas, the survey was designed and acquired using broadband methodologies and long 12s records. To achieve this deep imaging objective while maintaining the shot-point interval at 18.75m and vessel speed at 4knots, the acquisition was performed using a shot-overlap strategy with the individual shots then recovered via de-blending. In this paper we will use two adjacent sequences from this dataset (identified by the red line in Figure 2) to describe the method:

- sequence A: the minimum time gap between adjacent sources (TL1=12s) is equivalent to the desired trace length (TL2=12s), so no overlap is present (i.e. the dataset is unblended). This sequence is used to create a synthetic dataset using the time gaps between adjacent sources recorded for sequence B.

- sequence B: the minimum time gap between adjacent sources (TL1) is 8 s, and TL2 is 12 s. The bottom part of the dataset is blended.
In the following, we show the results of the overlap removal for sequence A and B.

Sequence A

Figure 3 shows a shot gather recorded by an outer cable after the synthetic blending, and the stack of the raw dataset; we can observe the contrast in amplitude between signal and blending noise.



(a) (b)

Figure 3 *Synthetically blended sequence A: (a) shot record; (b) stack. Channels and cross-lines are 12.5 and 6.25 metres apart, respectively.*

Figure 4a-b shows a portion of a shot record (green rectangle in Figure 3a) before and after the deblending process. The unblended data in Figure 4c contains coherent events (possibly from side-scattering) that can be used as a reference to evaluate the proposed de-blending procedure. The final result appears much cleaner than the unblended dataset: this feature is expected, and is due to the harsh noise attenuation applied to remove the blending noise. The comparison of the stacks of the blended, de-blended and unblended datasets is shown in Figure 4d-f. Both from the shot records and the stacks, we can note that the blending noise has been completely removed, at the expense of some

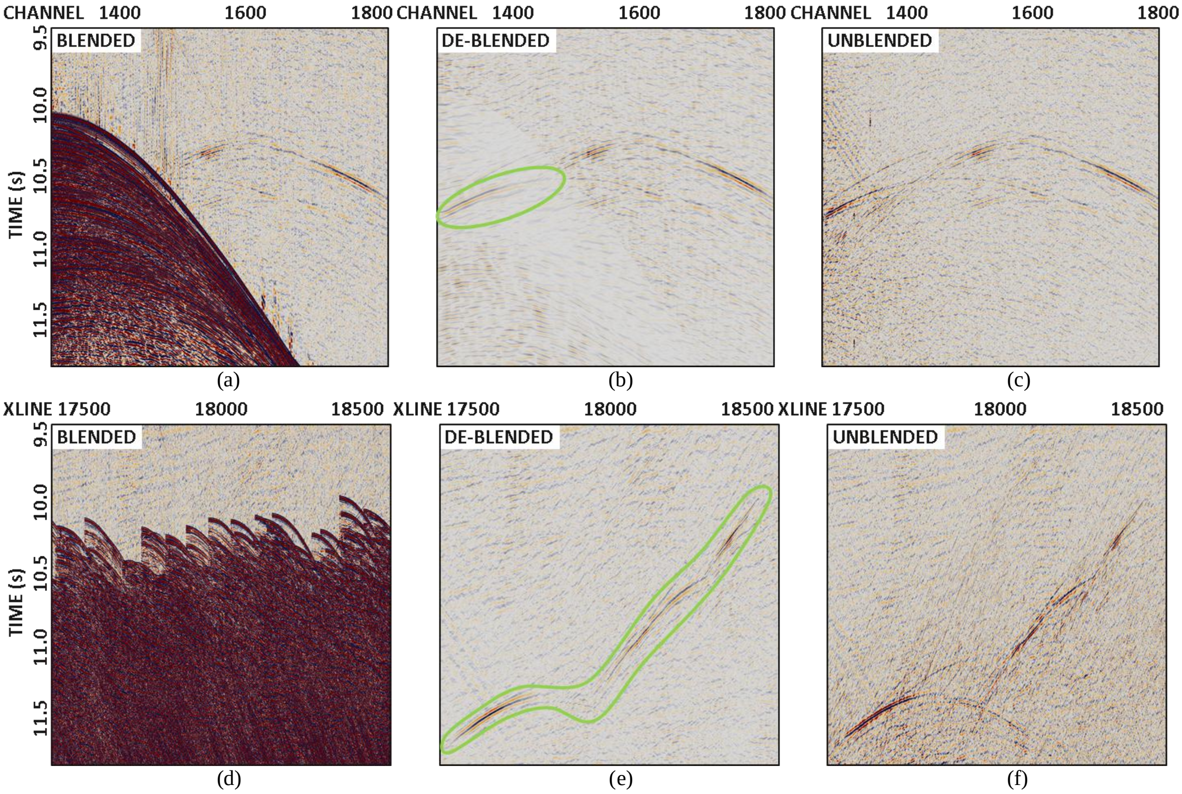


Figure 4 *Sequence A - close-ups: (a) shot record - blended; (b) shot record - de-blended; (c) shot record - unblended; (d) stack - blended; (e) stack - de-blended; (f) stack – unblended.*

signal loss; in other words, the de-blending procedure allows the retrieval of some, but not all, of the signal. We tested that this signal would have been completely lost by muting the overlap zone.

These observations are supported by a quantitative analysis of the signal amplitude in the green area of Figure 4b: the difference in RMS amplitude between the blended and the unblended stacks is around 20 dB, whilst the difference between the unblended and de-blended stacks ranges around 5 dB. This difference, which is partially explained by random-noise reduction, is considered an acceptable compromise given the stated deep structural imaging purposes and acquisition constraints.

Sequence B

The overall appearance of the sequence B dataset is very similar to that of the synthetically blended dataset shown in Figure 3. The de-blending is performed using the same technique and the same parameters optimized for sequence A. The comparison between the blended and the de-blended datasets is shown in Figure 5. As in the synthetic case, we can note that the blended noise has been removed. There is no benchmark to compare our results against; however, if we observe Figure 5b, we can note several events which continue across the line that identifies the de-blending area, with amplitudes slightly attenuated. Figure 5d shows evidence of sub-horizontal events. Further velocity model building and imaging is needed in order to assess their nature.

Conclusions

This abstract describes a de-blending method that can be used to extract more information from continuous-recording data. A two-step rank reduction filter, which exploits the irregularity in time of the shooting, has been developed and tested. The aim of applying this filter is to retrieve as much signal as possible (note that the amplitude contrast between deep and shallow events prevents full

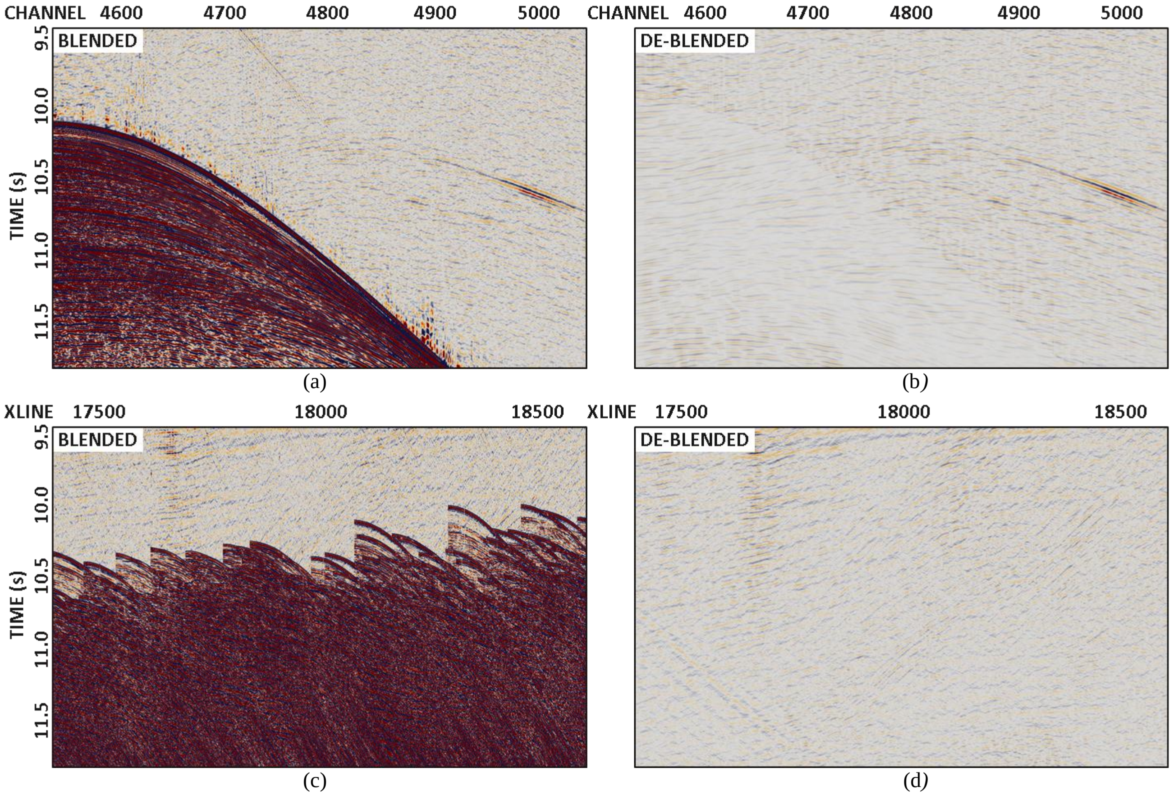


Figure 5 *Sequence B - close-ups: (a) shot record - blended; (b) shot record - de-blended; (c) stack - blended; (d) stack - de-blended.*

signal reconstruction). When applied to a synthetically blended test sequence, the proposed method delivered recovered signal within 5dB of the unblended signal. Application to a test sequence blended in acquisition successfully removes the blending noise and is expected, coupled with further velocity model building and imaging, to provide useful information on deep structures that would have been lost with a conventional approach.

Acknowledgements

The North Carnarvon 3D Data is courtesy of Dolphin Geophysical and TGS. We thank Dolphin's management for the permission to publish these results.

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