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Blended de-signature: a new approach to source separation

A blended dataset is nothing but an unblended dataset generated by a blended source, and if the source signature of this blended source is known, the dataset can be de-blended by deconvolution. This paper illustrates a new methodology that uses this idea to perform source separation when the source signatures of the blended sources are different and known. This methodology does not require random delays, and can be used jointly with other de-blending methods. The effectiveness of the suggested methodology, alone or combined with other de-blending steps, is demonstrated using a synthetically blended real dataset obtained combining datasets from two different sources firing on the same streamer. The results suggest that, for a similar level of residual overlap energy, the application of de-signature before other deblending steps improves the signal preservation of the whole de-blending processing.

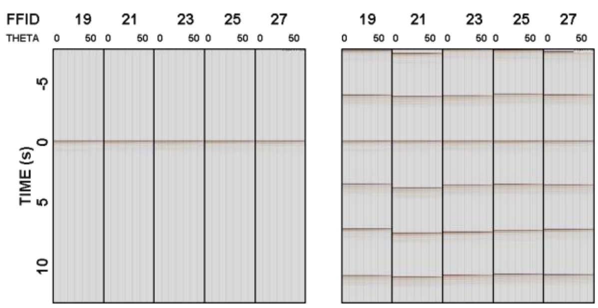
Introduction

The efficiency uplift provided by marine blended acquisition has lead to major developments of the de-blending techniques in the last years. By allowing energy overlap between adjacent shots, the acquisition time and cost decreases while keeping the fold intact. Several authors have investigated this topic: among others, we mention Berkhout (2008), Mahdad et al. (2011), Maraschini et al. (2012), Cheng and Sacchi (2015), Kumar et al. (2015), Robertsson et al. (2016). These works focus mainly on almost simultaneous blended acquisitions, i.e. when the difference between the blended sources firing times is usually lower than one second. Recently some work has been performed on shot records extracted from continuous recording, where the time distance between the adjacent shots is in the order of several seconds (Aaron et al. 2016, Maraschini et al. 2016, Seher and Clarke 2016). The de-blending processing proposed by these works can be very different, but they are all based on the variability, random or periodic, of the firing times.

In this work we introduce a de-blending step that can be used by itself or together with other techniques (in the following example it is used before rank reduction de-blending), not based on firing time variability but on the use of differing sources during acquisition, as well as on the knowledge of the corresponding directional far field source signatures. This method can be used both for almost simultaneous shooting and for continuous recording with overlap.

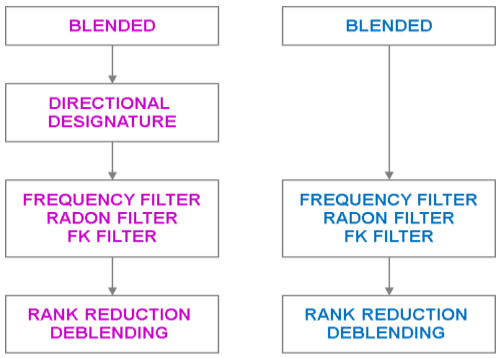
Method

In the proposed method a blended shot record is not seen as the sum of two independent shots, but as a unique shot generated by a "blended source signature", which is the combination of all the source signatures fired within a given time interval. In order to create the blended source signature we need to have the directional far field signatures (that can be obtained for example from near field hydrophones (Hargreaves et al. 2015)), as well as the position and the firing time of each source. The comparison between an example blended and unblended directional signature for 5 adjacent shot records is shown in Figure 1.



(a) (b)

Figure 1 *a) Example of an unblended signature for various shot points and take-off angles.; (b) Example of a blended signature.*



(a) (b)

Figure 2 *Processing sequences used for the tests: a) processing sequence 1; b) processing sequence 2.*

Once the blended signature is created, a shot record (longer than the desired trace length for output) is extracted from continuous recording data, and directional de-signature is applied shot by shot. The result of this step is a partially de-blended dataset. In order for this method to work properly, the source signatures of adjacent shots should not be identical. As this de-blending technique leaves residual blending noise in the de-blended dataset, it can be applied before any of the other de-blending processes. In the following example, de-signature de-blending is applied before filtering and rank reduction de-blending (Maraschini et al 2016). It is very important to note that this technique does not require any type of variable delays, random or periodic, between shots.

Synthetically blended dataset with different sources – a de-blending example

In order to test the methodology, we synthetically blended a real dataset. The unblended dataset is from a 30 km 2D sail line acquired in the Norwegian sector of the North Sea. The source configuration comprised a broadband source (Telling et al. 2014) and a conventional source, firing flip-flop at intervals of 18.75m. The cable was flat, towed at 30m depth with 640 hydrophone groups with an interval of 12.5m and first offset 150m. The sample interval was 2ms and total record length 7.5s. The data were prepared with a 1.5Hz 18dB/octave low-cut filter followed by targeted attenuation of aliased energy, linear noise and swell-noise. For both sources the far field signatures are obtained from near field hydrophones recordings. Both the datasets and the signatures are blended using a firing sequence that reproduces the natural dithering for sources firing at constant spatial intervals of 7.5m. Examples of a blended and the corresponding unblended shot records are shown in Figure 1 a and b respectively.

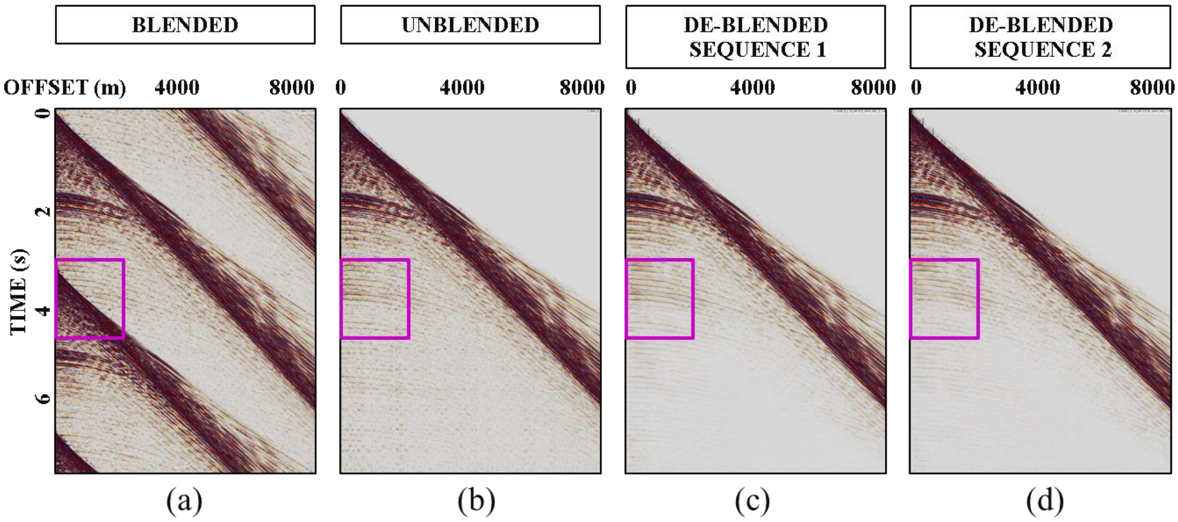


Figure 3 *Example of a shot record: a) blended; b) unblended; c) de-blended with processing sequence 1; d) de-blended with processing sequence 2.*

In order to test the method, we implemented 2 processing sequences for de-blending (Figure 2) and we compared the results (Figure 3 c and d respectively). In these flows the de-blending procedure is composed of up to three steps:

- Directional de-signature: The de-signature step is described in the method section, and is only used by processing sequence 1; it is performed shot by shot using a longer trace length than the desired one (for each shot record, assuming that the source we would like to extract is fired at 0ms, we use data between -6500 and 1500ms).
- Filtering in the common shot domain: it is used on all processing flows and is based on physical considerations: first we apply a time dependent frequency filter that removes frequencies that can not be present at a certain depth; then we remove with a Radon filter events that are too slow to belong to the signal we would like to retrieve, and finally we remove events that are too steep.
- Rank reduction de-blending: it is a 3D method based on the rank reduction filter (Maraschini et al. 2016); it is used in both processing sequences. The parameters of the rank reduction de-blending are harsher for processing sequence 2 than for processing sequence 1, in order to obtain a residual overlap energy level comparable in the de-blended datasets estimated by the two methods.

Figure 4 allows us to analyse the results obtained by the two processing sequences. All pictures refer to a zoom of the same shot record (magenta boxes in in Figure 3), where some signal is visible. Figure 4a shows a zoom of the blended shot record and Figure 4b of the unblended shot record.

Figures 4 c and d show the de-blended shot record and the corresponding residual noise (difference between de-blended and un-blended data) obtained applying the first 2 steps of processing sequence 1, i.e. without using the rank reduction de-blending. This result is important because the first two steps of processing sequence 1 do not require any variability in the firing time delays and can therefore be applied in situations where de-blending techniques based on randomness of the overlap can not be used. Figure 4 e and f show the de-blended result and the corresponding residual noise obtained applying the rank reduction de-blending after de-signature and filtering. The results are cleaner, but the impact of this final step is not major.

We then compared the results obtained by processing sequence 1 with the results obtained by processing sequence 2. Figures 4 e and g show the zoom in the magenta box of Figures 3 c and d of the de-blended shot records obtained by the two methods. We can note that the amount residual overlap energy for the two methods is comparable, but processing sequence 1 allows a better signal preservation. This is more evident observing Figure 4 f and h where the difference between the de-blended datasets and the unblended ones are shown: in Figure 4 h some hyperbolic events, not visible in Figure 4g, are clearly visible, indicating an amplitude loss in the signal.

Figure 5 shows the stack of the blended line versus the unblended one and the de-blended ones obtained by processing sequence 1 and 2. The results confirm the considerations we made from the shot records: the signal preservation is better for processing sequence 1 than for processing sequence 2 (see for examples events indicated by the magenta arrows).

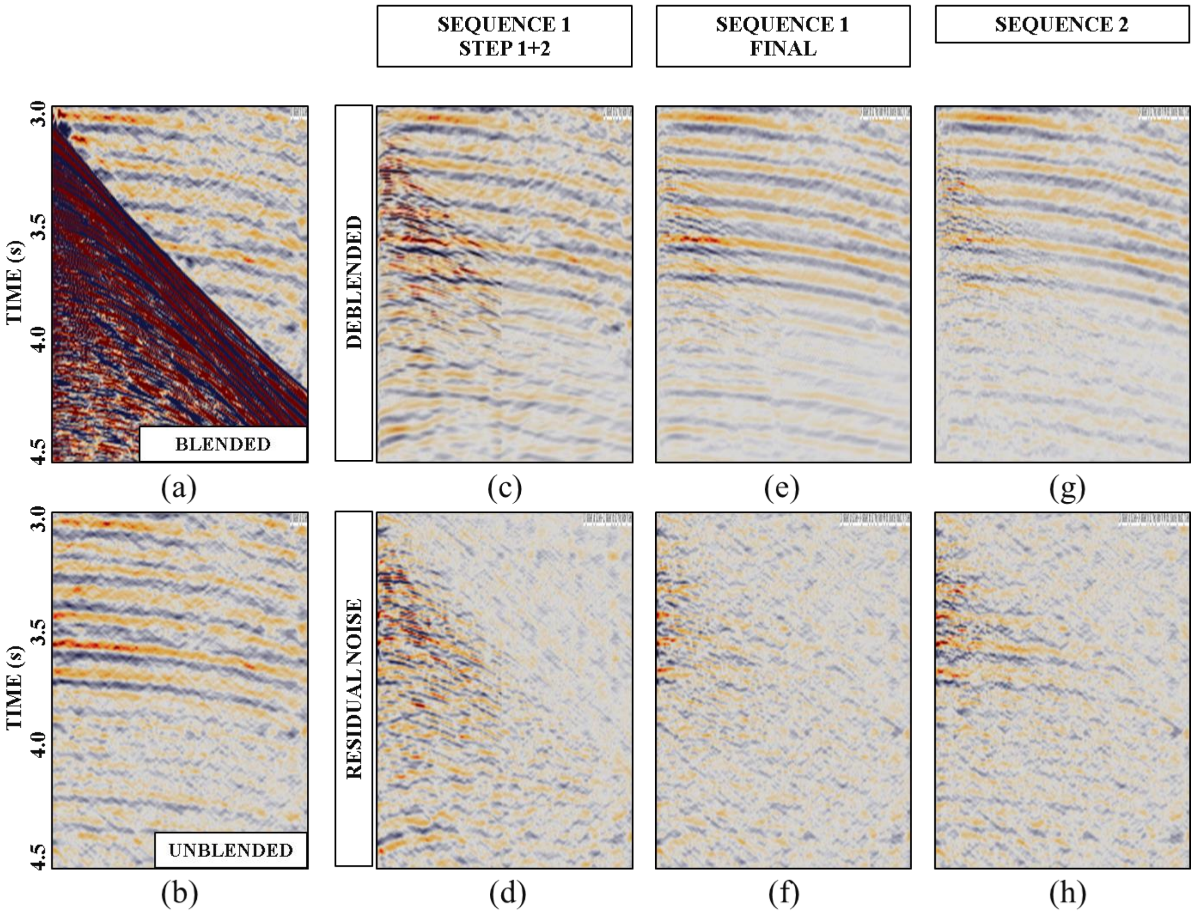
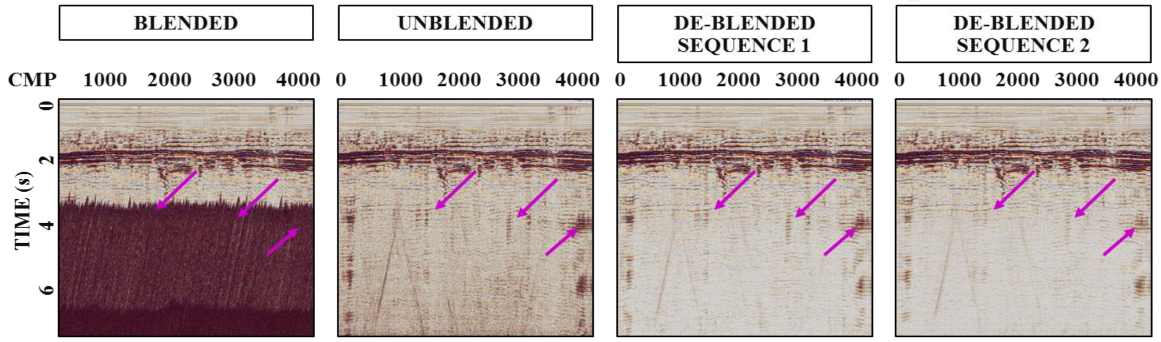


Figure 4 *Example of a shot record – zoom (magenta boxes in Figure 3): a) blended; b) unblended; c) de-blended with the first 2 steps of processing sequence 1; d) difference between unblended dataset in (b) and de-blended dataset in (c); e) de-blended with processing sequence 1; f) difference between unblended dataset in (b)and de-blended dataset in (e); g) de-blended with processing sequence 2; h) difference between unblended dataset in (b)and de-blended dataset in (g).*



(a) (b) (c) (d)

Figure 5 *Example of a shot record: a) blended; b) unblended; c) de-blended with processing sequence 1; d) de-blended with processing sequence 2.*

Conclusions

This paper illustrates a new methodology to perform source separation that can be used when the source signature of the blended sources are different and known. This methodology does not require random delays, and can be used jointly with other de-blending methods. The idea behind the proposed methodology is to assume that a blended shot record is an unblended shot record generated by a blended source, and if we are able to estimate the blended source signature, a deconvolution should be able to extract the de-blended dataset. This assumption has been proved valid using a synthetically blended real dataset obtained combining datasets from two different sources firing on the same streamer. The application of the de-signature de-blending, alone or combined with other de-blending steps, allows to strongly attenuate the blending noise. The results shown in this paper suggest that, for a similar level of residual overlap energy, the application of the de-signature before the other de-blending steps improves the signal preservation of the whole de-blending processing.

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