A seeded approach to deblending OBN data

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Summary

Inversion deblending routines typically require many internal iterations along with external looping with various parameters to achieve satisfactory results that can be used for further processing and imaging. In this paper we present a method to improve deblending results, while reducing run time and cost. In Ocean Bottom Node (OBN) data, the direct arrival is the highest amplitude event and the easiest to identify with confidence in the seismic data. The proposed seeded inversion deblending will combine inversion deblending along with a signal model with high confidence to achieve better deblended results, and is faster and lower in cost than the inversion deblending alone. We will show comparisons of a real data volume in time domain and the Reverse Time Migration (RTM) imaging from a recent sparse OBN survey.

Introduction

Marine seismic surveys are typically acquired in a manner where some level of blending is expected in the raw data. The blended interference includes the arrival of the next shot and the arrivals of other sources from other vessels. Depending on the target depth, number of sources and vessels used, and time between shots many processing sequences benefit from or require source deblending to be performed at an early stage of the processing sequence (Xuan et al, 2022).

Inversion deblending methods, such as the Iterative Shrinking Thresholding Algorithm (ISTA) presented by Sun in 2022, have become the work horse and primary deblending tools for most modern projects. However, the inversion deblending, as other inversion processes, can suffer from needing many iterations and possible external loops to appropriately separate the energy into their appropriate shots. In this paper we propose an alternate method to use the inversion deblending routine, pairing an initial condition with the inversion.

In this paper we will present data examples, from a sparse node multi-client survey acquired in 2023, showing time domain comparisons of inversion and hybrid deblending as well as migrated volumes.

Method

The Amendment Phase 2 sparse OBN survey was acquired in the Gulf of Mexico using two triple source vessels, utilizing the compressed flip-flap-flop method (Udengaard et al, 2023). All sources from a single vessel would be activated with a four second window in time with listen time of approximately 19.5 seconds. Combined both source vessels acquired about 1.9 million unique source points for the duration of the survey. The processing sequence, and presurvey testing, indicated the ideal deblending routine would be ISTA. Due to the very long offsets acquired into most node gathers, in excess of 80 km, the trace length used for the deblending was 63 seconds. Running inversion deblending with nearly two million traces and long record lengths pushed the inversion deblending to long runtimes.

In order to improve runtime and data quality a test was performed to seed the inversion deblending with an initial solution, similar to methods used for other inversion processes like Full Waveform Inversion (FWI) and water column inversion. The source direct arrival is the highest amplitude recorded event in an OBN dataset, and beneficially is also very easy to identify out to reasonable offsets. Isolating the source direct arrival can serve as a good initial condition for the inversion deblending.

The proposed seeded inversion deblending starts with generating a high confidence signal model. To generate this signal model the raw deblended data is dealiased, using Linear Move Out (LMO) or stretch free normal moveout, to flatten the direct arrival followed by a tightly windowed amplitude burst attenuation. After flattening the direct arrival the high confidence signal model is generated using a coherency tool that isolated the highest amplitudes, for example a locally windowed 3D curvelet transform (Candès et al, 2006), with amplitude thresholding keeping only the highest amplitude events. The signal model is then reblended to all interfering times and subtracted, along with the signal model, from the blended data. The key in generating the signal model is not to isolate all of the direct arrival into the model, but to identify only direct arrival energy into the model. A major benefit of this initial step is the next shot energy is significantly attenuated. After removing the high confidence signal model from the blended data, the inversion deblend routines can be parameterized to run more quickly utilizing fewer iterations, but we can also make each step size in the internal iterations run at a finer sampling. Inversion deblending typically spends more than one third of the iterations just identifying the direct arrival.

After the inversion deblending completes, the resulting signal and residual models are summed along with the high confidence signal model. Because the high confidence signal model is added back directly the only energy assigned to the model must be signal.

Examples

Figure 1 shows a comparison of inversion deblending alone versus the seeded inversion deblending method in an area with a single vessel, three sources, acquiring data by a near offset line into a single OBN location. The inversion deblending shows leakage and signal damage at the higher frequencies of the direct arrival. The high confidence signal model derived at the direct arrival significantly reduces the signal leakage. The seeded inversion deblending method result has significantly less leakage around the direct arrival, indicated by the green arrow. Beyond the direct arrival improvement, the reflections at the near offsets are more continuous.

A longer offset example is shown in Figure 2. This source line also has interference from the other source vessel utilized during the survey. The two source vessels acquire data simultaneously with different time intervals, causing the diagonal pattern of interference in the blended gather. Both the inversion deblending and seeded inversion deblending methods produce good results on removing the interference from the other vessel. At these longer offsets we can see an improvement in the deblending at the diving waves above the direct arrival when using the seeded inversion deblending method.

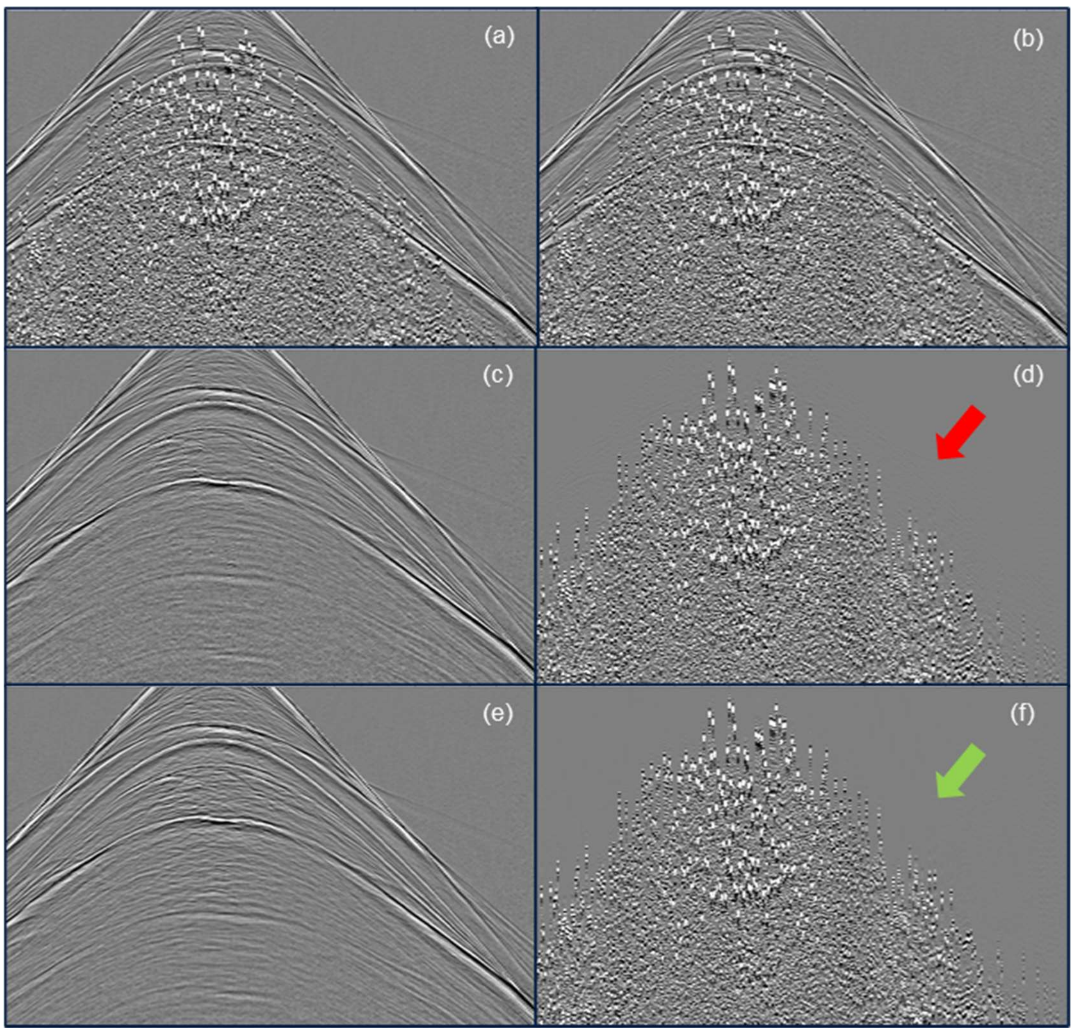

Figure 1 – Single near offset source line into one node location: (a) and (b) blended input data, (c) inversion deblending alone result, (d) blended input to inversion deblending alone difference, (e) seeded inversion deblending result, and (f) blended input to seeded inversion deblending difference.

Seeded inversion deblending

Conclusions

Using an initial solution and removing that from the entire inversion process improves the inversion deblending results. As with many inversion routines, some prior knowledge of the solution will prevent the routines from falling into local minima or allow the inversion to converge with less iterations. The seeded inversion deblending presented in this paper achieves superior results over the inversion deblending alone method, while requiring less iterations. Thus gives the rare result that is faster, better, and cheaper.

The seeded inversion deblending process appropriately assigns energy to the correct shots, this not only removes interference from other vessels, but also cleans the next shot energy significantly and uncovers weak signal in the overlapping area. Figure 3 shows a 25 Hz RTM of the input data and two methods of deblending. The sub-salt reflectors are more clearly imaged with the seeded inversion deblending method, which clearly indicates source energy has been assigned to the correct traces.

We have shown the results of this process using OBN data, but the process should also work successfully on marine streamer data, isolating the direct arrival and water bottom reflector in the high confidence signal model prior to the inversion deblending process.

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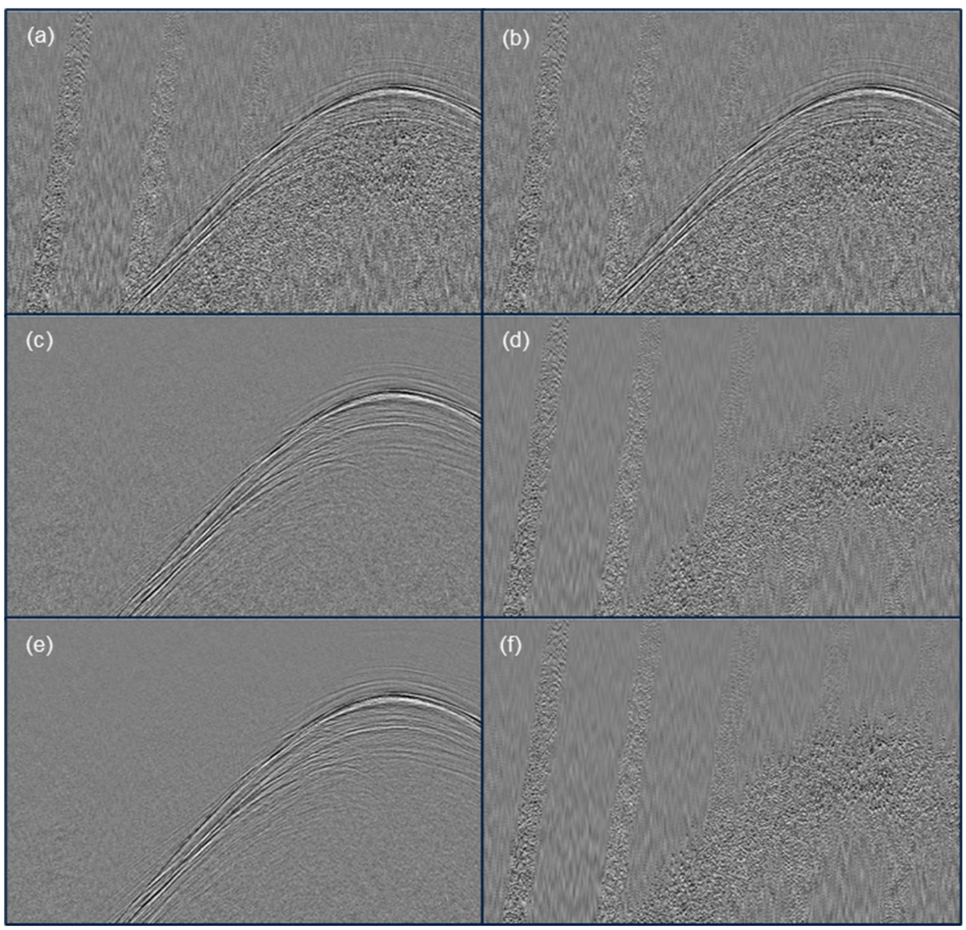

Figure 2 – Single long offset source line, with interference from second source vessel, into one node location: (a) and (b) blended input data, (c) inversion deblending only result, (d) blended input to inversion deblending only difference, (e) seeded inversion deblending result, and (f) blended input to seeded inversion deblending difference.

Seeded inversion deblending

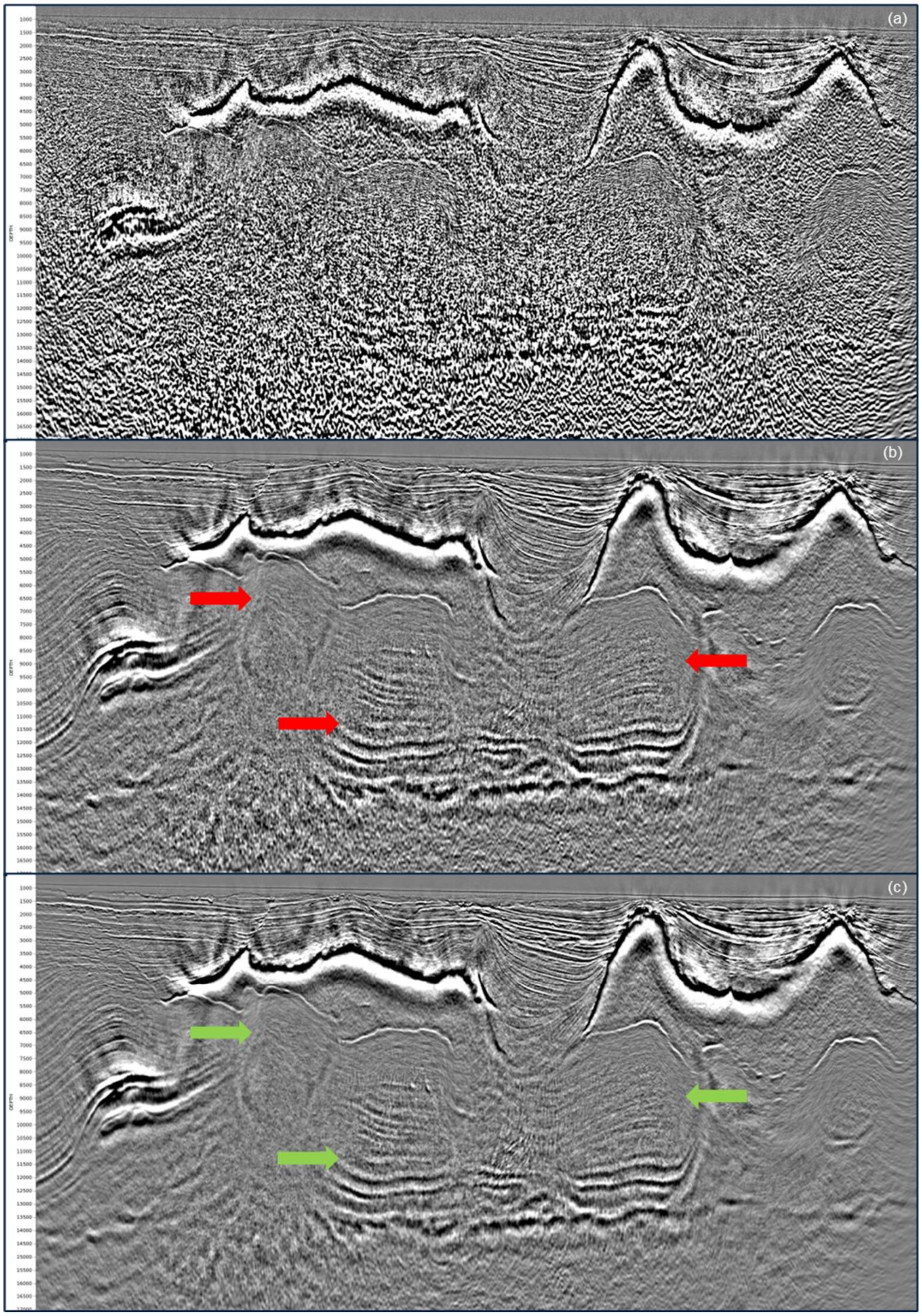

Figure 3 – 25 Hz RTM comparisons of (a) blended input, (b) inversion deblending, and (c) seeded inversion deblending. The hydrophone component was migrated using the downgoing wavefield imaging condition. At depth the blended noise interference is significantly lower when using the seeded inversion deblending procedure. Both methods produce similar results above the salt bodies.

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