Introduction

Blended acquisition, or simultaneous shooting (Berkhout, 2008), is a technique used to reduce survey time and increase source density. Blended acquisition can involve multiple source vessels in addition to multiple source arrays on each vessel. With this style of acquisition, sources are fired more frequently than the expected listening time, or record length, of the survey; this introduces seismic interference onto the recording of each shot. Common practice in data processing is to apply a deblending process to the raw blended data as an initial processing step before additional time domain processing and or depth domain imaging. There are many deblending processes described throughout the literature in both 2D and 3D domains, these include simple denoising techniques (Liu, 2014), F-K domain (Masoomzadeh, 2018), F-X domain, tau-p domain (Zhang, 2012), and inversion-based methods (Abma, 2010; Mahmood, 2011; and Ayeni, 2011). Many methods involve multiple iterations and handling of the unmodelled energy, or residuals. Mahmood (2012) investigated multiple deblending approaches on synthetic marine streamer data. This paper will investigate various deblending methods, and their effects on imaging on a deep-water Ocean Bottom Node (OBN) survey.

Acquisition

In the Spring and Summer of 2019, a large multi-client blended OBN survey was acquired in the Gulf of Mexico. The survey was designed with two objectives in mind, both imaging and FWI velocity model update. This survey consisted of 2700 nodes deployed with 1000m by 1000m separation, and a dense infill node area of 300 additional nodes with 500m by 500m separation. The source grid was 50m inline interval with 100m source line spacing. Because deep FWI velocity model update requires long offsets; this survey was designed to achieve 40km crossline offset for each node location. Each node by design would record in excess of one million shots. In order to acquire all shots within the battery life of the node, and reduce the operational cost, the survey was acquired in a blended style as follows. Three dual source vessels were used for the survey, resulting in six unique sources firing independently. Additionally, because of the desire to acquire long offset diving waves for the FWI velocity model building, the sources were not fired in traditional flip-flop method. The two sources on each vessel were fired nearly simultaneously, with plus-minus one second time dither from the pre-plot source location. With only one vessel firing, this method will limit the highest amplitude portion of the data, the direct arrival and initial reflections and multiples, from interfering with the much lower amplitude diving waves and refracted arrivals. Figure 1 shows the effects of six source blending on a near source line to a node. The time dither of the same vessel source interference can be seen as contaminating wavelets, indicated with red arrows, before and after the expected arrivals. Additional interference from other vessels can be seen in the reflection portion of the record and before the refracted arrivals, indicated with green arrows.

![Figure 1 A near source line extracted from a node gather.](image-url)
Method

Several methods of deblending have been examined to attenuate the blended energy, with each method being investigated in both time domain and image domain, using downgoing wavefield RTM imaging. Source dither times for the survey correspond to the modification of the nominal source location by approximately 2.0 to 2.5 meter inline distance from a pre-plot source location, at normal source vessel speeds. All three source vessels used the same random, white, and non-repeating dither table, with varying starting locations. The time dither of sources randomizes the signal from interfering vessels ensuring no two vessels are generating multiple consecutive coherent shots simultaneously (Lynn, 1987). Various deblending methods will change the amount of crosstalk, or noise, in the imaged gathers and stacks. Figure 2 shows the results, in time slice, of an iterative denoiser deblending process, the same as used to generate the images in Figure 3. Low amplitude diving wave events can easily be seen after deblending at offsets exceeding 15km, indicated with blue arrows in Figure 2(b). In Figure 2(a) the variability in blending interference can be seen due to the frequency of shooting during the primary lines and when the source vessels are transitioning from one line to the next. This variability in the blending must be considered when selecting deblending parameters and methods. During line changes the source vessels typically transition from location-based shot frequency to time-based shot frequency, and the other source vessels continue to acquire production shots. The time dither and line turns require any deblending process to honour irregularity in source geometry.

![Figure 2 A time slice at 7000msec of one node (a) before deblending and (b) after deblending. Notice the diving wave events outside the direct arrival, highest amplitude even on images, uncovered by the deblending process. The grey area is the location of all shots recorded by the node. Areas of more consistent blending interference occur when source vessels are turning between sail lines, indicated by red arrows.](image1)

Figure 3 shows RTM images of raw blended hydrophone data, an iterative denoising approach to deblending, and a hybrid approach including inversion and iterative denoising. The majority of events seen in the deblended images are also seen in the imaging of the raw blended data. The iterative denoising method used in this example consists of statistical high amplitude anomaly identification, applied in both source line and source point domains (equivalent to inline and crossline), and coherency estimation. The coherency estimate is then reblended and subtracted from the initial raw blended data. The process is repeated a second time with slightly more aggressive parameters used to identify remaining high amplitude anomalies. A final pass of statistical high amplitude anomaly removal is applied before the RTM imaging. This method differs from inversion techniques because there is no attempt to numerically minimize the residual energy, though the residual is analysed visually in time domain and the process is iterated until the residual is deemed sufficiently small.
Parameter selection for identification of anomalous energy was performed with care given to protect both visible reflection and diving wave energy. The hybrid approach utilizes an iterative inversion approach on the initial highest amplitude events, primarily the direct arrival and water bottom multiple events. This is followed by iterative denoising and additional inversion deblending for the lower amplitude coherent events.

Figure 3 The hydrophone component input to RTM using the downgoing wavefield imaging condition, and RTM images of one receiver line. (a), (d), and (g) show one sail line raw, iterative denoise deblend, and hybrid inversion-denoise deblend. (b), (e), and (h) show RTM image inline of corresponding input data. (c), (f), and (i) show RTM crossline image.

Additional deblending techniques are investigated including inversion based local 3D tau-p, inversion based local 3D F-Kx-Ky, and hybrid approaches using inversion methods and iterative denoising routines. Hybrid deblending techniques can be used to isolate very high amplitude events, such as the direct arrival and water bottom multiples, and remove their impact on blended data before utilizing tau-p or F-K transforms.
Conclusions

Deblending is a process that removes noise and crosstalk from the imaged volume, but significant care must be taken to leave signal content unharmed when determining the distribution of recorded energy onto the output traces. In the case of deep water OBN surveys, where there is very little background noise in the imaging frequencies, inversion based deblending algorithms should account for all recorded energy with minimal residual energy. Non-inversion based deblending processes should be less aggressive, allowing more blended energy on gathers, in order to retain all low amplitude signal content. Some processes between deblending and imaging may require more aggressive noise attenuation and the same care should be taken to prevent signal loss.

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References


