Seismic interference noise removal

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Summary

We show that seismic interference noise, as well as random noise, on 3-D marine survey shots can be detected and suppressed. This process allows boats to reduce down time when another crew is operating in the same area.

The random noise suppression part of our algorithm uses f-x-y prediction filters where x and y represent receivers and shots, respectively. The seismic interference removal part has a built-in f-x-y domain noise detection mechanism and is applied as f-x domain prediction error filters to the noisy frequencies of the shots.

The application of the process to field data showed that amplitude versus offset properties of reflections are preserved.

Introduction

Marine seismic crew interference has been known to be a problem for quite some time. Time-sharing between crews operating in the same area eliminates the problem, but leads to downtime with economic consequences. Solutions to the problem were sought as early as the 80's (Akbulut et al., 1984, Lynn et al., 1987). Most methods find scalers that will reliably suppress or mute out portions of data contaminated with high-energy noise. Muting (Brink, 1991), as well as scaling (Pokhriyal et al., 1991, Hawkins et al., 1998), cause significant loss of signal because muting completely eliminates signal, and scaling scales down underlying signal along with the noise.

Other methods of marine interference noise removal have been published. Huaien et al. (1989) made use of the randomness of the marine interference noise in the common offset or common receiver domains and applied *f-x* prediction filters to remove it. Dragoset (1995) built a noise model for propeller noise and subtracted this noise by an adaptive filtering scheme Recently, Gulunay and Pattberg (2001) presented the application of the method described in this paper to two initial data sets. In this paper, the preservation of the AVO effect by the process is demonstrated on a new data set.

Description of the method

Our method is *f-x-y* domain based and works on each frequency slice of data independently. This way, a frequency that doesn't contain interference noise can be treated differently from frequencies that do.

We start by staggering the shot records of a single subsurface line by their shot stations, as shown in Figure 1, and work in overlapping space (source and receiver) and time windows. This type of arrangement is necessary for random noise suppression, but, for interference noise suppression, one can also work without staggering the shots. The data is first NMO-corrected with a velocity function close to primary velocities. A small window size is chosen (e.g., 10 shots x 20 receivers x 500 ms) so that primary events become approximately planar events in the *t-x-y* domain. Once we have such a cube of data, we transform it from time to frequency and generate the frequency slices.

The detection part of the algorithm scans each frequency slice and compares the amplitudes averaged over a shot to the amplitudes averaged over the whole slice (A "shot" in this paragraph and the next one refers to the Fourier transform samples at a given frequency for a given shot). The average amplitude of a shot is also compared to neighboring shots. Once certain thresholds are exceeded, the shot is assumed to be contaminated with interference noise. Such a shot is treated by application of a very short (3-point) prediction error filter (1D PEF) designed from the shot assuming that the shot has mono dip noise higher in strength than the underlying signal that may have a more complex dip structure. More specifically, a 2-point PEF in the form (1,-p) is designed from the first two autocorrelation lags and a 3-point filter (-0.5p*,1,-0.5p) is formed from it. Note that (*) represents complex conjugation. The complex number p is the one-step-ahead predictor and contains implicit dip information about the noise. Such a filter predicts interference noise from a future and a past receiver and subtracts it from the current receiver.

As a last step in the process, two 2D forward-backward spatial prediction filters (2D PF), (one 2D PF for each neighboring quadrant) are designed. To preserve signal content we use an edge effect free filter design method known as the modified covariance method. In this method, the filter never exceeds the edge of the data slice. The final filter is made of four quadrants, opposite quadrants across the origin being obtainable from each other by conjugate symmetry. 1D PEF application on shots for coherent noise suppression and 2D PF application for shot reconstruction and random noise suppression can be applied independently, but if applied together, coherent noise suppression is run first. Both algorithms need multiple shots.

Field data set

Figure 2 shows two unprocessed CMP gathers of a 3D marine survey. The AVO measured along the reflectors identified by a black line on the right of each gather is displayed at the bottom of the figure. Figure 3 shows the same gathers after their shots were processed for seismic interference and random noise suppression. A comparison of these figures shows that the process preserves AVO behavior. Figures 4 and 5 show three consecutive shots before and after the process, and Figure 6 is the difference. The stacks from the same data before and after seismic interference noise removal are shown in Figures 7,8, and 9. We observe that the process preserves reflection energy while suppressing seismic interference noise and enhancing spatial continuity.

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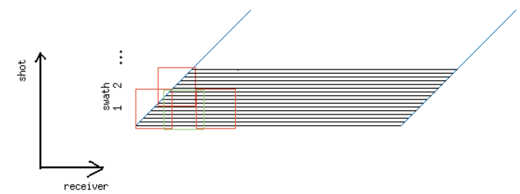

Figure 1. Surface diagram showing shots and overlapping shot-receiver windows.

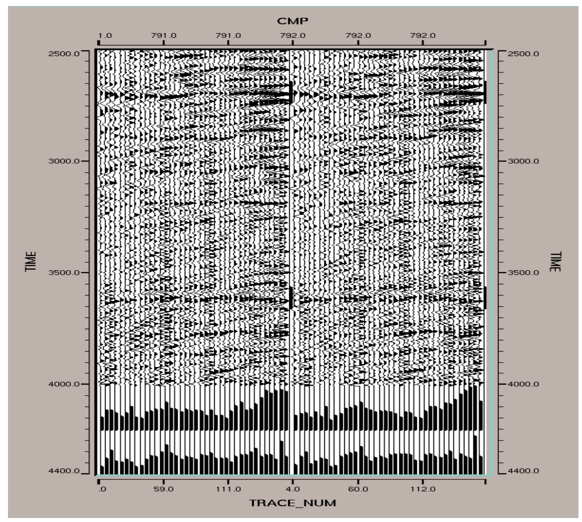

Figure 2. Amplitude analysis on two input CMP gathers.

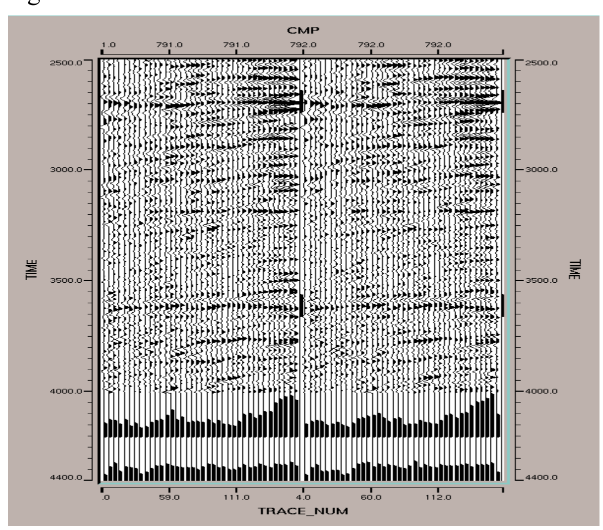

Figure 3. Amplitude analysis on the CMP gathers of Figure 2 after seismic interference and random noise suppression. The analysis shows that AVO behavior is preserved.

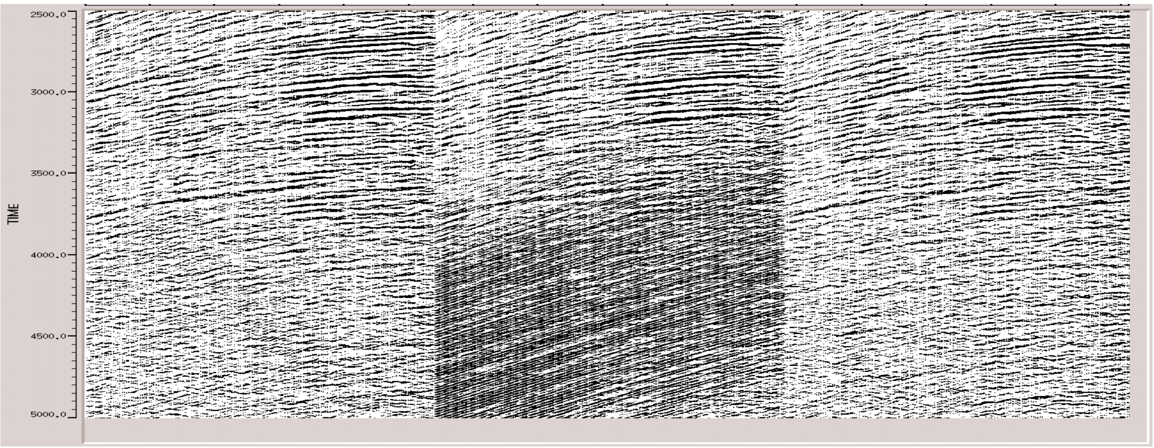

Figure 4. Three consecutive shots. The middle shot has interference noise.

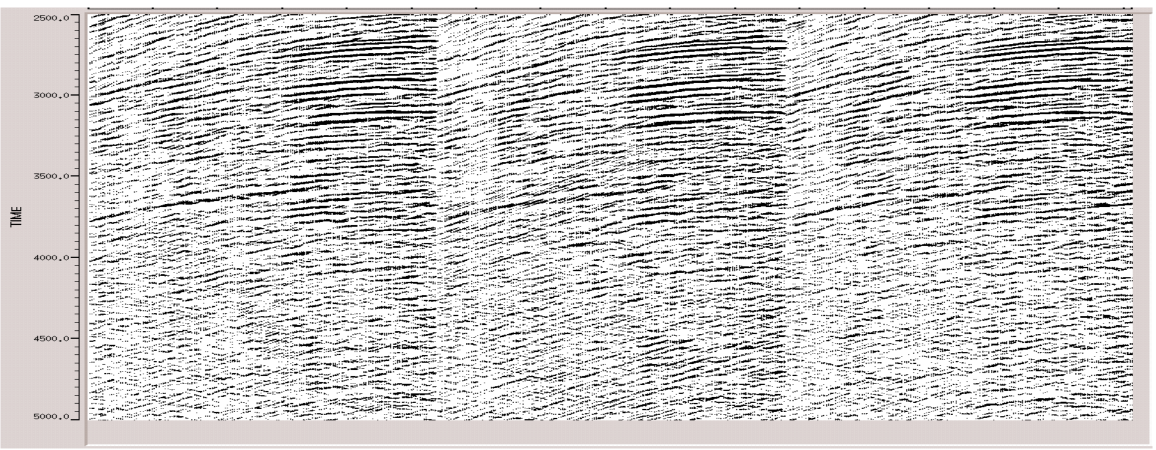

Figure 5. Same shots after seismic interference and random noise suppression.

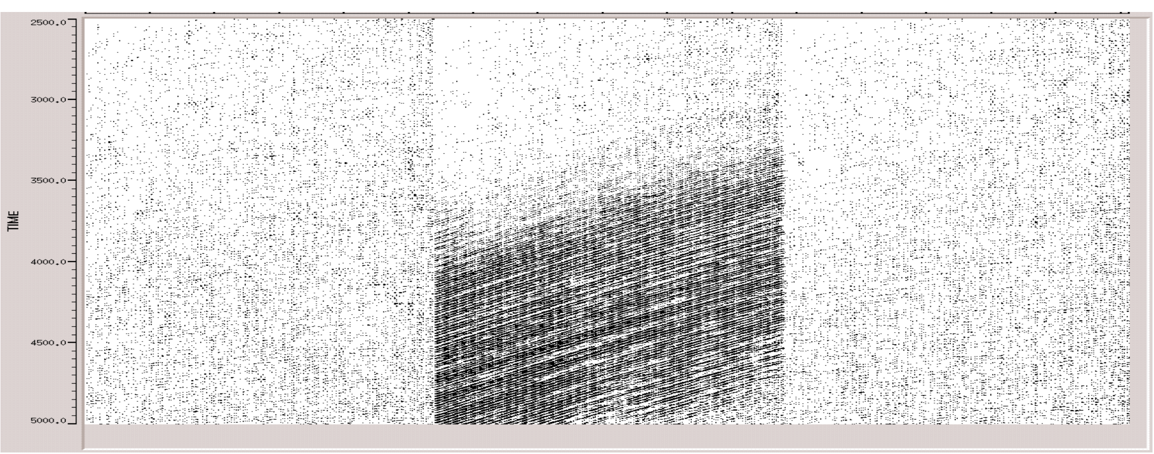

Figure 6. Difference between input and output.

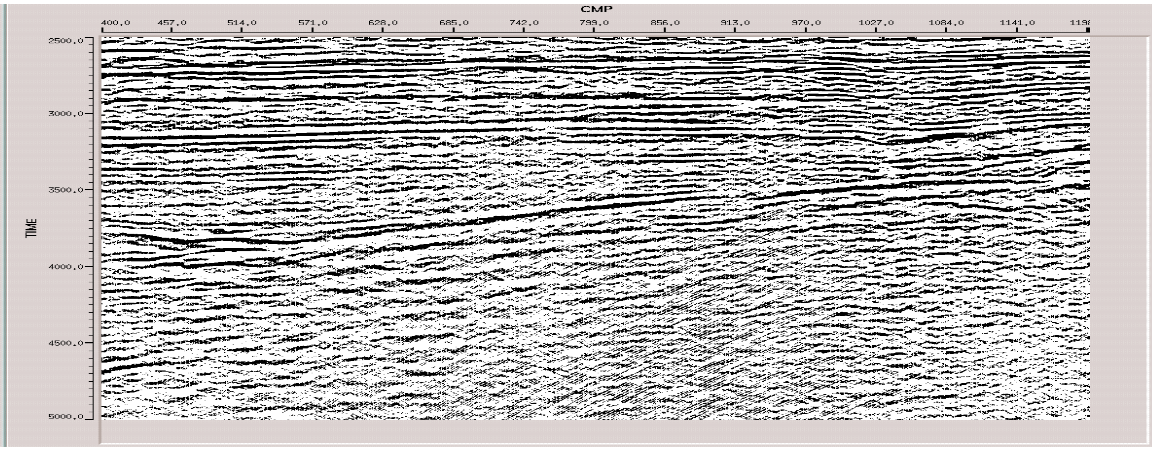

Figure 7. Stack of raw input gathers.

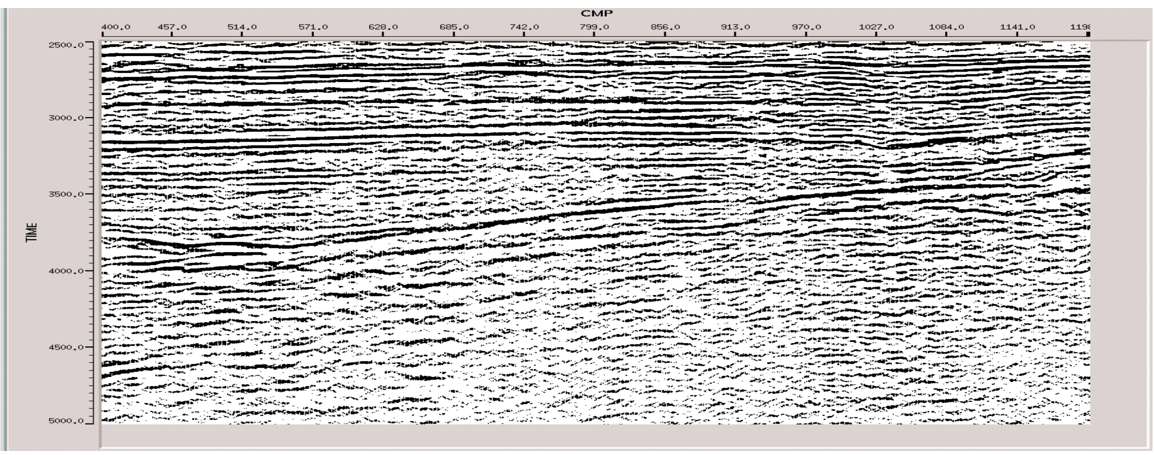

Figure 8. Stack after seismic interference and random noise removal.

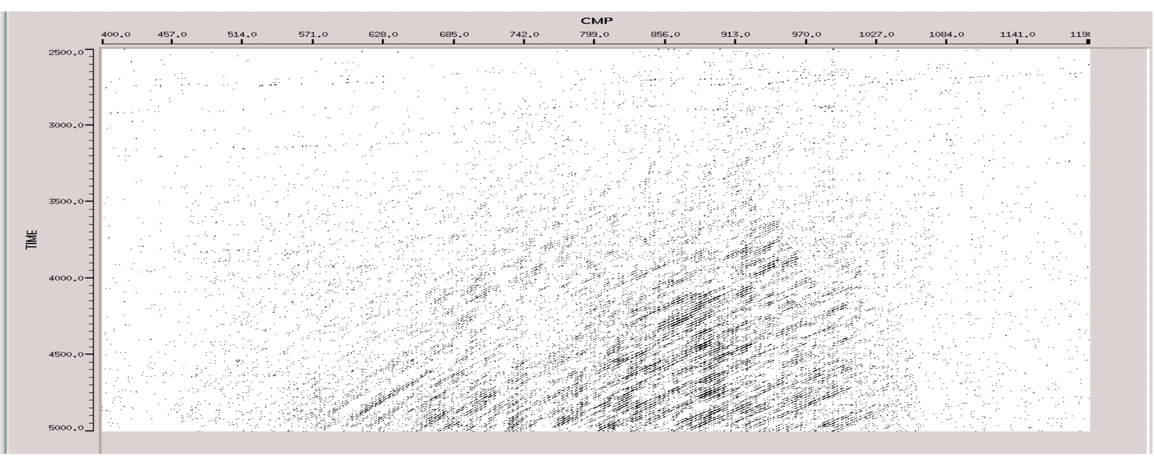

Figure 9. Difference between the two stacks.