A-13 SEISMIC CREW INTERFERENCE AND PRESTACK RANDOM NOISE ATTENUATION ON 3-D MARINE SEISMIC DATA

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Abstract

This paper presents a method of removing strong seismic interference noise as well as random noise from shots acquired in 3-D marine surveys. This process will allow boats to reduce down time when other crews are operating in the same area.

The method is applied to each frequency slice of the frequency-source-receiver volume obtained by time only Fourier transform of a small time-space (source and receiver) volume of data. These volumes overlap in time and space. At a given frequency, magnitudes of the complex samples are first analyzed to determine which shot has interference noise. Once a shot is determined to be contaminated with interference noise, a 3-point forward-backward prediction error filter (1-D PEF) is designed and applied to remove this noise. After all contaminated shots in the frequency slice are processed, the slices are filtered with a two-dimensional prediction filter (2-D PF). Such a filter suppresses random noise as well as the residues of coherent marine interference noise since this noise is not predictable with a 2-D PF designed from the whole slice. Once all frequency slices of all time-space gates are processed, the samples are transformed to the time-space domain and overlapping time-space windows are blended.

The detection logic of the algorithm assumes that only a few of the shots in a slice are noisy. Design and application of the 1-D PEF relies on the assumption that interference noise is much higher in amplitude than the underlying signal and has a single dip. The 2-D PF part of the algorithm requires that interference noise is not predictable from shot to shot. Large shot-to-shot variations of the arrival times of interference noise, and difference in the frequency content between noise-free shots and noisy ones, help satisfy these requirements. This paper presents the application of the process to two data sets, one from the North Sea and the other from the Gulf of Mexico.

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 is used to eliminate the problem but leads to downtime with economical consequences. Solutions to the problem were sought as early as the 80's (Akbulut et al. 1984, Lynn et al., 1987). Most methods work on finding scalers that will reliably suppress or mute out portions of data contaminated with high-energy noise. Muting (e.g., Brink, 1991), as well as scaling (Pokhriyal et al., 1991, Hawkins et al., 1998), cause significant loss of signal since muting get rids of 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.

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 and window size is chosen to be small (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. The average amplitude of a shot is also compared to neighboring shots (Figure 2). 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) 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.

Once all noisy shots in the frequency slice are treated, one can recalculate a slice average as well as shot-to-neighboring-shots ratios and repeat the procedure if necessary. Figure 5 shows a shot contaminated with such a mono dip noise of unknown origin (data from the North Sea) and Figure 6 shows the result of applying the iterative 1-D PEF process. Figure 7 shows the difference. Two things are worth noting here: 1) the signal underneath the interference noise is well preserved; and 2) the remaining amounts of seismic interference noise will further be removed by the 2-D PF described below.

As a last step in the process, two 2-D forward-backward spatial prediction filters (one 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 as shown in Figure 3. The final filter is made of four quadrants, opposite quadrants across the origin being obtainable from each other by conjugate symmetry as shown in Figure 4. 1-D PEF application on shots for coherent noise suppression and 2-D 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.

Figure 8 depicts a stacked section from the Green Canyon area of the Gulf of Mexico. Interference noise is strong and overpowers the deep data. We applied a 1-D PEF and a 2-D PF, as discussed above, to the shot records after the shots were NMO corrected. Figure 9 shows good suppression of seismic interference and random noise after the processes were applied.

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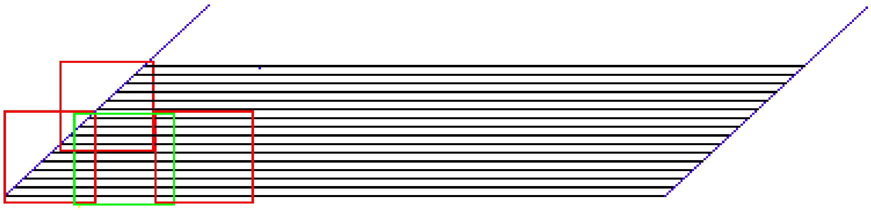

Figure 1. Surface diagram showing shots (horizontal axis) and the overlapping short-receiver windows.

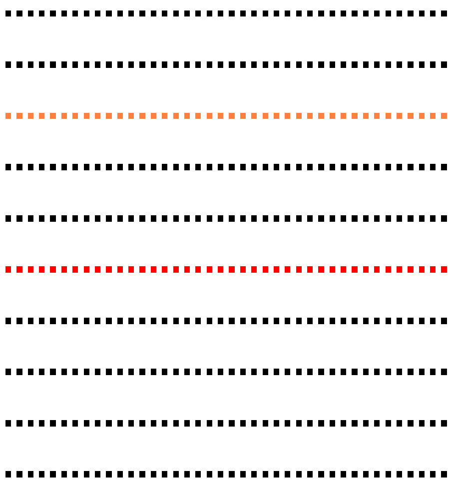

Figure 2. A frequency slice made of 10 shots and 40 receivers. Different shades represent different magnitudes.

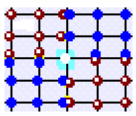

Figure 4. The full filter is formed by summing four quadrants. Size of the quadrants is 3x3.

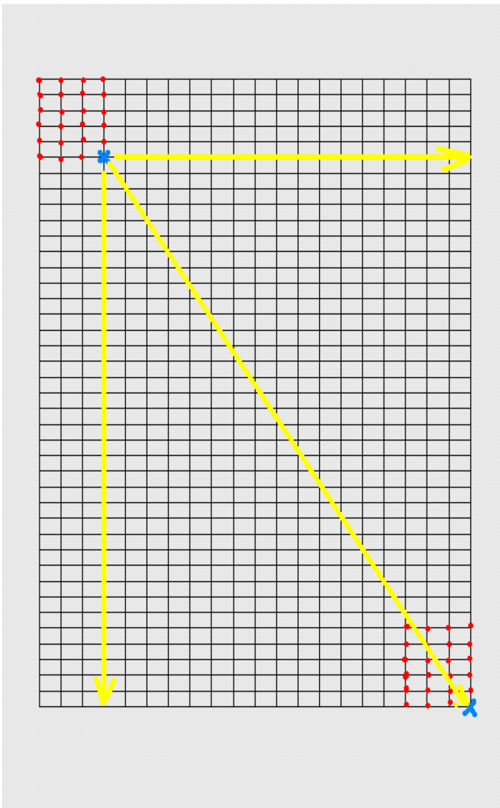

Figure 3. Filter placement for an edge effect free filter design. Filter points are always fully on data. Size of the quadrant is 6x4.

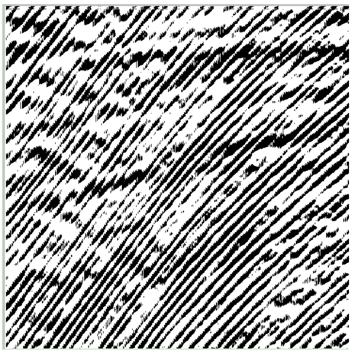

Figure 5. A noisy shot from the North Sea contaminated with steeply dipping noise of unknown origin.

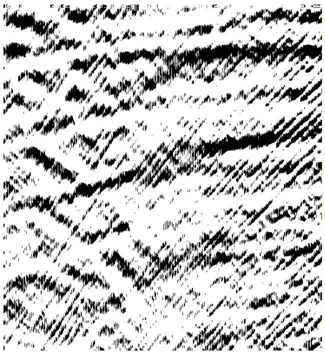

Figure 6. Data from Figure 5 after application of 1-D PEF.

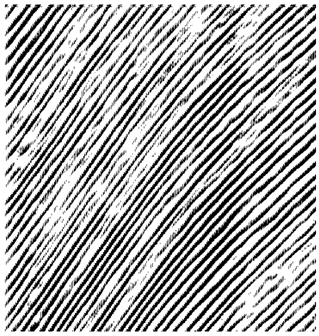

Figure 7. Difference between the input and output of the 1-D PEF process.

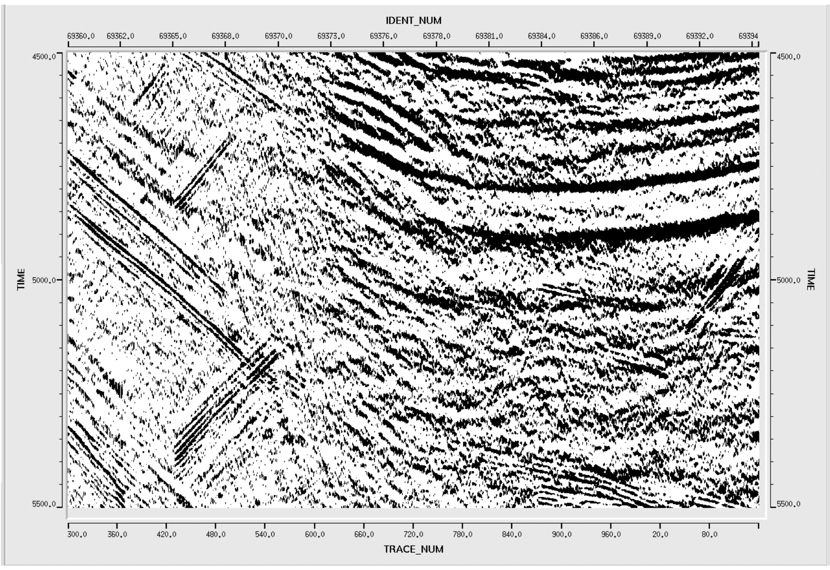

Figure 8. Stacked section from the Gulf of Mexico with seismic interference noise.

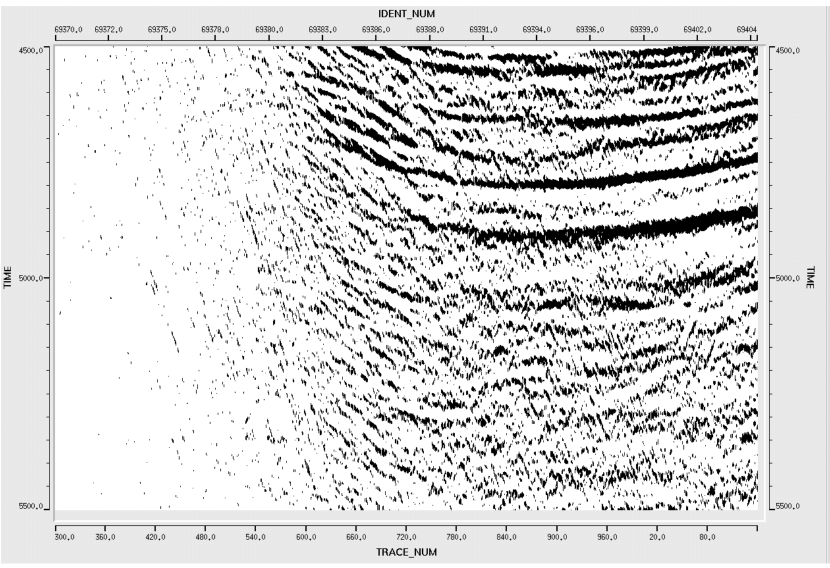

Figure 9. Data from Figure 8 after application of 1-D PEF and 2-D PF processes for seismic interference and random noise suppression.