Seismic Noise Removal a Feasibility Study

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SUMMARY

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To be able to make efficient use of seismic data in interpretation and modeling it is important that it has been processed as accurately as possible. One such processing step is de-noising. This paper considers three time-frequency de-noising methods, all of them built up within the same framework, but they use different approaches to separate signal and noise. Examples of the various methods are demonstrated using a real dataset affected by swell noise.

Introduction

Data recorded by a seismic survey will always be contaminated with noise. Seismic noise can have different origins (Olhovich, 1964), where some types of noise is easier to remove because the source or reason for it is known, e.g. multiples. But noise caused by for instance bad weather (Smith, 1999) might be more difficult to get rid of because it is very random and has overlapping frequency content with the wanted seismic signal.

The basis of this study is the published works of Thomas Elboth (Elboth, et al., 2008) and Maïza Bekara (Bekara, et al., 2008). Both of these methods represent time-frequency filtering with statistical selection. However Elboth et al. employ a simple method to find a suitable threshold value whereas Bekara et al. uses a more comprehensive approach. By further development of these methods the goal is to fully understand their potential and limitations, and develop a more accurate and automatic algorithm for noise removal.

Method

Time-frequency filtering (TFDN)

The standard TFDN algorithm uses a sliding window in space and time (Elboth, et al., 2008). The size of the window can be adjusted depending on what kind of dataset that is used, e.g. a shot gather needs a shorter window in space than a common offset gather because of the move out.

Inside the window the traces are transformed to frequency domain and their amplitudes are calculated. Only the centre trace in each window is to be checked for noise. To investigate if the centre trace is affected by noise its amplitude is compared with a reference amplitude of assumed good quality for each frequency. The reference amplitude is the median (or lower quartile) amplitude within the whole window. If the amplitude of the centre trace is larger than the median times a factor, it is attenuated to the level of the median. This is repeated for all frequencies specified by the user. The frequency range depends on what kind of noise the data is affected by.

When the maximum frequency is reached the spectra of the attenuated centre trace is transformed back to time domain and output. The sliding window is moved and the same procedure is repeated.

This original algorithm works well, and has been in use for a number of years. However, it is believed that it could be optimized, especially as concerns the use of median as reference amplitude. It would also be nice to reduce the number of user parameters. Optimal determination of parameters can be difficult for a non experienced user, and can require extensive testing.

TFDN with “master trace”

The first attempt to refine the standard TFDN has been to replace the computation of the median amplitude with an amplitude from a computed master trace. To build the master trace the energy for each trace within the window is calculated. Traces that had energy below the median energy were correlated with the median energy trace. If the correlations satisfy some given parameters the traces are stacked together with the median.

At the end the stacked trace is divided by the number of contributed traces and the master trace has been created. For each frequency the amplitude of the master trace is multiplied with

a given factor, and the threshold is compared with the amplitude of the centre trace just as in the original TFDN method.

TFDN with the Bekara method

The second refinement of the standard TFDN comes from ideas borrowed from (Bekara, et al., 2008). By using more comprehensive statistics it is possible to detect which amplitudes that most likely are noise and which are regular data. For each frequency this method is used to sort the amplitudes into noise and regular signal, and finding a value of the maximum recommended amplitude size, the threshold. That value is compared with the amplitude of the centre trace in the window. If the centre trace is bigger than the threshold it is attenuated. The advantage of this method is that it requires little user interaction, i.e. the user just has to define the window size and the maximum frequency to attenuate.

Results

The examples shown here are computed employing the same input data (Figure 1), i.e. a 200 traces - 8seconds marine seismic shot-gather with significant swell noise.

Results are shown for all three TFDN implementations. The size of the sliding window is the same for all tests, and the maximum frequency where noise is expected is set to 15 Hz, experience has shown that this is enough to remove most swell noise.

Figure 1: Input shot gather with swell noise

To compare the results the signal-to-noise (S/N) ratio of the data are computed, defined as:

$$\text{S/N-ratio} = \frac{\text{Energy of output}}{\text{Energy of input} - \text{energy of output}}$$

By comparing Figure 2 with the input data (Figure 1) it is clear that noise has been removed, but there are still some swell-noise in the left part of the data. Also, some parts of the sea floor are removed. Most of the remaining noise can be attenuated by running the algorithm once more on the output data. The problem with the sea floor might be solved by applying the algorithm with different max frequency in different parts of the data. A choice could be to use 10Hz on the first seconds, which includes the sea floor, and 15 Hz or more on the remaining part.

The signal to noise ratio of the data shown is 1.78. However, what is removed from the sea floor is not noise so the ratio does not give a fully true answer.

Figure 3 show the result obtained using the master trace method. It removes a bit more than the original TFDN, but it takes away too much of the sea floor.

The computed signal to noise ratio is 1.20, however the sea floor contributes much to this value so it does not give a useful estimate.

The method might not work that good on shot gathers because of the move out. However, it might be well suited on common offset gathers, and the plan is to apply it in this domain later.

Figure 4 shows the last method tested here, i.e. the Bekara method. The signal to noise ratio is estimated to 1.64, and the result looks very good. This algorithm hardly removed anything from the sea floor, and at the same time it removes at least the same amount of noise as the original version.

The result is very satisfying because this is a method that not requires many user parameters, so it fulfills the goal of a more automatic algorithm.

Figure 2: Top: Output. Bottom: difference plot for original TFDN

Figure 3: Top: Output. Bottom: difference plot for master trace

Figure 4: Top: Output. Bottom: Difference plot from the Bekara

To obtain an even better result an option might be to apply different methods on different parts of the dataset. E.g. use the Bekara method on the first three seconds which includes the sea floor and then the master trace method on the remaining part of the data. Based on the results obtained in this paper this may improve the final result.

Conclusion

The original TFDN algorithm has already proved useful and effective (Elboth, et al., 2008). However, as demonstrated in this paper improvements are possible within the same framework by considering alternative statistical selections of feasible thresholds. In general, the family of TFDN methods has proved quite efficient for noise removal for removal of both random and coherent noise, as long as the data containing coherent noise can be sorted in a way so it appears random.

References

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