

CDP Noise Attenuation Using Local Linear Models

Todor I. Todorov*
SUNCOR Energy
ttodorov@suncor.com

and

Gary F. Margrave
The CREWES Project, University of Calgary

Summary

Seismic noise attenuation plays an important part in a seismic processing flow. Spatial prediction filters, like FX deconvolution, has been successfully applied to seismic volumes. However, since they require uniform spatial sampling, they are not suitable for noise attenuation of CDP gathers. A new method for noise attenuation on CDP gathers, based on local linear models, is developed. The process is applied to synthetic and real data from Alberta oil sands and shows a robust performance while preserving the AVO amplitude variations.

Introduction

Seismic noise attenuation plays an important part in a seismic processing flow (e.g. Yilmaz, 2001). The seismic noise can be divided into two groups: coherent and random. Generally, the coherent noise consists of real, physical events generated by the earth, however those effects must be removed to get an useful seismic data for structural and quantitative interpretation. Examples are surface waves (ground roll), guided waves, and multiple reflections. Random noise is not correlated from trace to trace. It includes a background ambient noise, effects of nearby production, swell, wind, instrumental noise and the effects of poor geophone coupling.

FX deconvolution (Canales, 1984) noise attenuation has been successfully applied on seismic volumes. In this publication we look at the problem of noise attenuation on CDP NMO-corrected gathers. To our knowledge, spatial-prediction filters, similar to FX deconvolution, can be extended to pre-stack data, however they require an uniform spatial sampling in offset direction, which is not the case for most of the seismic surveys. We develop a new method for noise attenuation based on local linear models in offset direction, which does not require uniform spatial sampling.

The Borga transform

Frequency slicing is a widely used approach in various processing techniques. A good example is time-variant spectral whitening (Yilmaz, 2001), where the seismic traces are band-pass filtered in narrow ranges and an estimated gain function is applied, followed by summing. We propose a different approach for computing frequency slices called Borga transform, which is viewed as the adjoint of the Gabor transform (the “Borga” name is adjoint of “Gabor”). It is a particular form of time-frequency decomposition.

The Borga transform computational steps are:

- Fourier transform the seismic trace
- for each frequency, window the real and the imaginary parts of the spectrum with a Gaussian window centered at the frequency
- inverse Fourier transform to get the frequency slice

Noise attenuation

The local linear models noise attenuation is based on two arguments:

- seismic signal amplitudes change in a local linear fashion in offset direction

Aki and Richards (1980) have shown us that within reasonable assumptions this is true. Almost all practical AVO analysis and pre-stack inversions are actually based on a linear amplitude change assumption.

- a particular seismic noise may have a narrower bandwidth compared to the seismic signal

By separating the seismic data into frequency slices we may separate different types of noise, thus lowering the relative strength of the noise versus the signal. For example, most of the source noise is low frequency, while power line noise has a very narrow, mid-range bandwidth.

The following summarizes the computational steps of the method:

- start with a CDP NMO-corrected gather
- using the Borga transform, generate frequency-sliced gathers
- for each frequency slice
 - for each time
 - estimate the amplitudes of all samples, based on a line fit of nearby samples
 - compute the absolute error between the actual and estimated amplitudes
 - correct the amplitude of the sample with the largest error
 - repeat, if necessary
- sum noise attenuated frequency-sliced gathers to obtain the final result

Examples

To test the method, an elastic wave AVO model, containing primary NMO-corrected events, is generated (Figure 1, a)). A random Gaussian, raised to power of 3, noise plus a low frequency linear event (Figure 1, b)) was generated and added to the AVO model (Figure 1, c)). Figure 2 shows the result of the noise

attenuation process. The noise has been removed successfully and most important, the AVO anomalies have been preserved. Figure 3 shows the AVO gather without noise, the noise attenuated result and the difference between the two. The difference has very low amplitudes and is a proof that no AVO related change has been removed or added.

Figure 4 shows an NMO-corrected CDP gather from the Alberta oil sands. Figure 5 is the same gather after noise attenuation. Figure 6 is the removed noise. The process has successfully removed both: the low frequency surface wave noise on the near offset traces and the majority of the uncorrelated random noise.

Conclusions

The new method of noise attenuation on CDP NMO-corrected gathers in offset direction shows a very robust performance, while preserving the relative amplitude changes. From the shown examples, we can conclude that it is an effective tool for removal of low frequency surface wave noise, high-amplitude spiky noise, and uncorrelated random noise.

The method can be extended to work simultaneously in inline-xline-offset directions for better performance especially for low fold data.

Acknowledgements

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References

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 Yilmaz, O., 2001, *Seismic data analysis*: SEG.

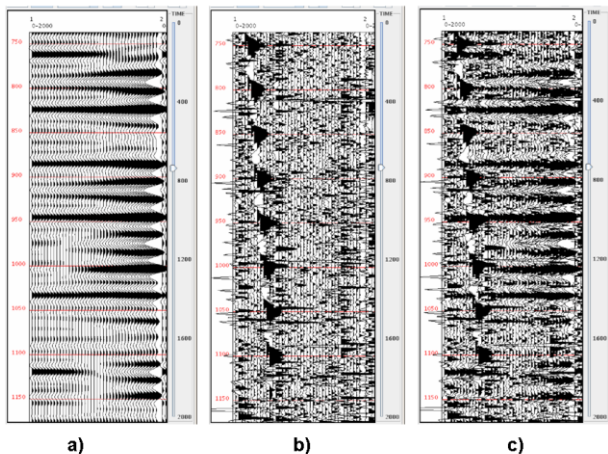


Figure 1: CDP NMO-corrected model a), noise added to the model b), noisy gather c).

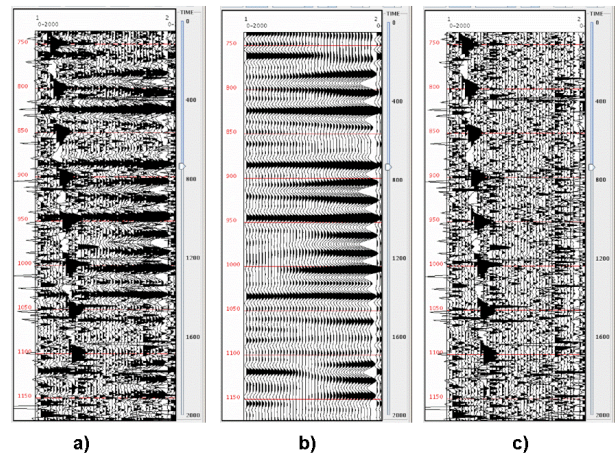


Figure 2: Noisy gather a), gather after noise attenuation b), and removed noise c).

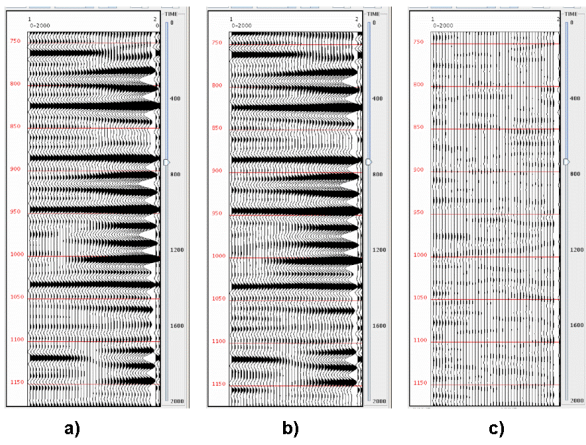


Figure 3: Avo model gather a), gather after noise attenuation b), and difference c).

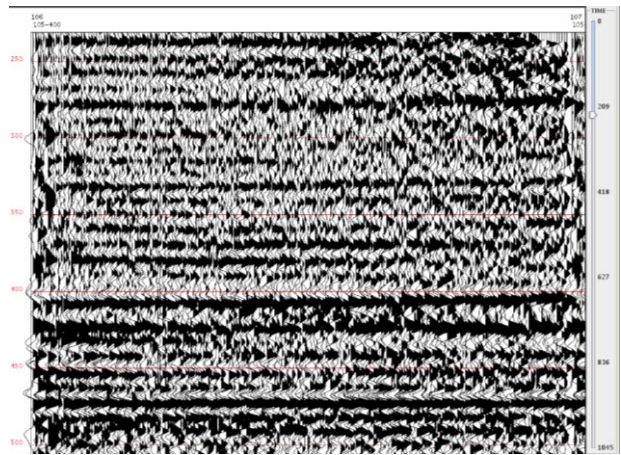


Figure 4: CDP NMO-corrected gather from Alberta oil sands.

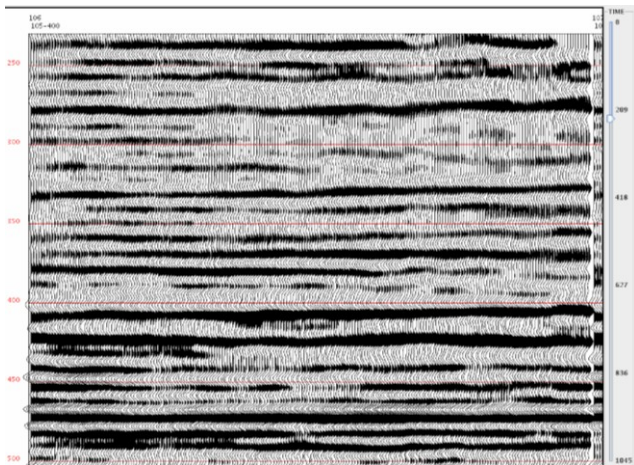


Figure 5: The noise attenuated CDP gather from Figure 4.

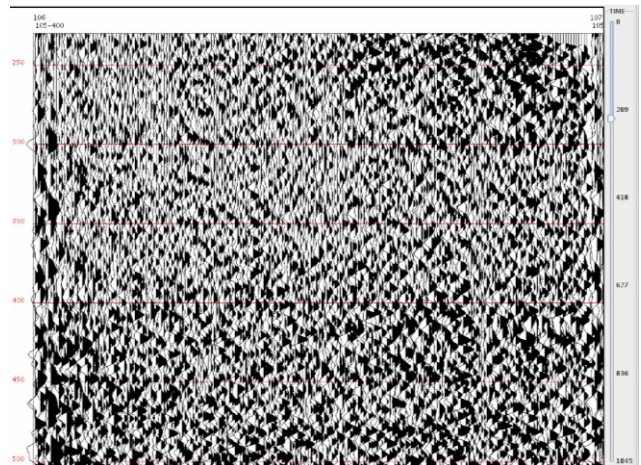


Figure 6: Noise removed from the CDP gather on Figure 4.