2011 CSPG CSEG CWLS Convention

Ground Roll Attenuation Using LWD

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Summary

We discuss Local Wavefield Decomposition (LWD) as a method to remove ground roll from controlled source seismic. LWD poses data reconstruction as an inverse problem that enforces sparsity in the coefficients needed to reconstruct the data. We discuss a strategy to automatically capture signal and noise in separate parts of LWD's data reconstruction. We also discuss results from applying the method to synthetic data, and irregularly sampled field data.

Introduction

Ground roll is a form of dispersive, low frequency, high amplitude noise that obscures useful information seismic exploration. Ground roll removal is an essential part of land seismic data processing. We are interested in modifying LWD (Sacchi et al. 2004, Theune et al. 2006) to automatically remove spatially aliased ground roll from non-uniformly sampled data. Traditional *FK* domain filtering is difficult to parameterize and is often used to remove ground roll. Aliasing in two dimensions may cause an event to appear to be dipping in the wrong direction, or, appear to be dipping in the right direction but with the wrong dip (Yilmaz, 2001). Aliasing thus causes ground roll and signal to overlap in the FK domain. In this case, ground roll may not be removed without producing a band limited signal (Linville and Meek, 2005). We investigate LWD as an alternative to *FK* filtering. To be more specific, we discuss a parameterization of local operators in terms of dip and central frequency to remove low frequency aliased noise from seismic reflections.

Methodology and Examples

LWD simultaneously models signal and noise using multiple subsets of local operators. A seismic record, $D(x,t)$, can be represented in terms of the local operators $B_k(x,t)$ and a matrix of coefficients (or shaping filter) $F_k(x,t)$. Each local operator is a compact operator designed to reconstruct one of the signal or the noise but not both. Every local operator is created with a distinct dip and/ or wavelet denoted by an index *k*. A local operator is convolved with a shaping filter, $F_k(t,x)$, to form a mode. Signal and noise are then reconstructed as a synthesis of their respective modes. The field data in Figure 3 is reconstructed using the local operators, shaping filters, and modes in Figure 1. The full reconstruction of the data, $\tilde{D}(t,x)$, is given by $\tilde{D}(t,x) = \sum_k F_k(t,x) * B_k(t,x)$, where t denotes time and x denotes offset. Notice that 2D convolution is used to translate the local operators in *t-x*; consequently, a simple local operator is shaped into a complicated signal.

It is clear one must estimate filter coefficients that will reconstruct the data. To calculate the filters, the following cost function can be minimized by a conjugate gradient solver: $\boldsymbol{J} = || \boldsymbol{D} - \sum_c \sum_k \boldsymbol{F}_k * \boldsymbol{B}_k ||_2^2 + \mu \sum_k |\boldsymbol{F}_k|_1$. To avoid an under-determined problem, the aforementioned cost function is L1 regularized. In other words, sparsity is used as a constraint to ensure a local operator will be used to only reconstruct parts of the data it fits well. This forces each local operator to reconstruct either the signal or the noise but not both. We test LWD`s ability to separate irregularly sampled overlapping events with a simple synthetic example shown in Figure 2. The method is also applied to field data in Figure 3; a shot gather where 22 traces out of 86 are randomly killed. Primaries obscured by ground roll in the original data are clearly visible in the reconstruction. The amplitude spectrum of the data in Figure 3 is presented in Figure 4. The full bandwidth of the primaries is recovered after processing even though the frequency content of the primaries and the ground roll overlaps.

Conclusions

We present a fast and fully automated method to remove spatially aliased irregularly sampled ground roll from controlled source seismic. LWD is analogous to a shaping filter where one tries to “shape” one signal into another. In this case, we shape an ensemble of operators into data. By virtue of the strong kinematic differences between reflections and ground roll, it is possible to estimate partial data reconstructions that model the ground roll component. In the examples presented, using separate source wavelets to model the signal and noise is paramount for signal and noise separation.

Acknowledgements

The Authors thank the industrial sponsors of the Signal Analysis and Imaging Group. Ken Kocon also thanks the sponsors of the Integrated Petroleum Geoscience program for their support.

References

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Figures

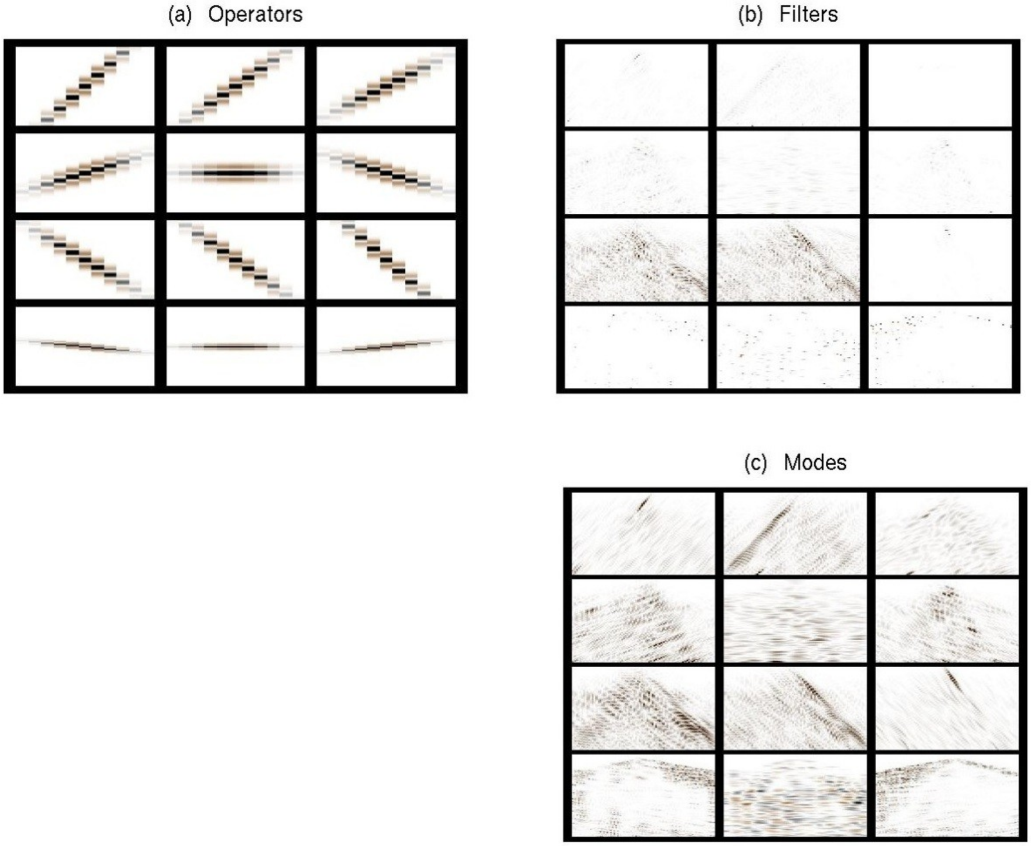

Figure 1 – (a) Compact local operators used to reconstruct the data shown in Figure 3 (a). The low frequency local operators in the top three rows of (a) model ground roll while the high frequency local operators in the bottom row model the reflections. (b) Shaping filters. Each shaping filter shapes one local operator in (a) into a mode seen in (c). The full data reconstruction is obtained by summing all the modes.

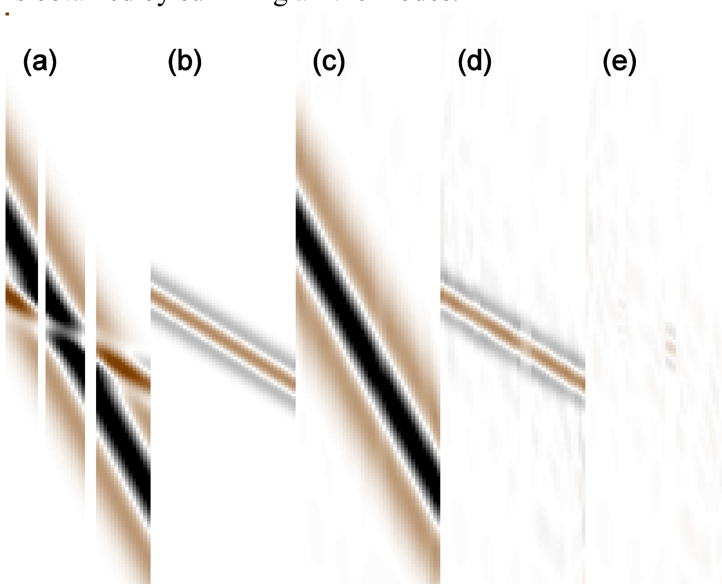

Figure 2 – Example of signal and noise separation using a synthetic primary and synthetic ground roll. The amplitude of the ground roll is twice that of the primary. (a) Input data, (b) Un-decimated synthetic primary used in (a), (c) noise model recovered by LWD, (d) clean data obtained as the interpolated difference between (a) and a decimated (c), (e) difference between (b) and (d).

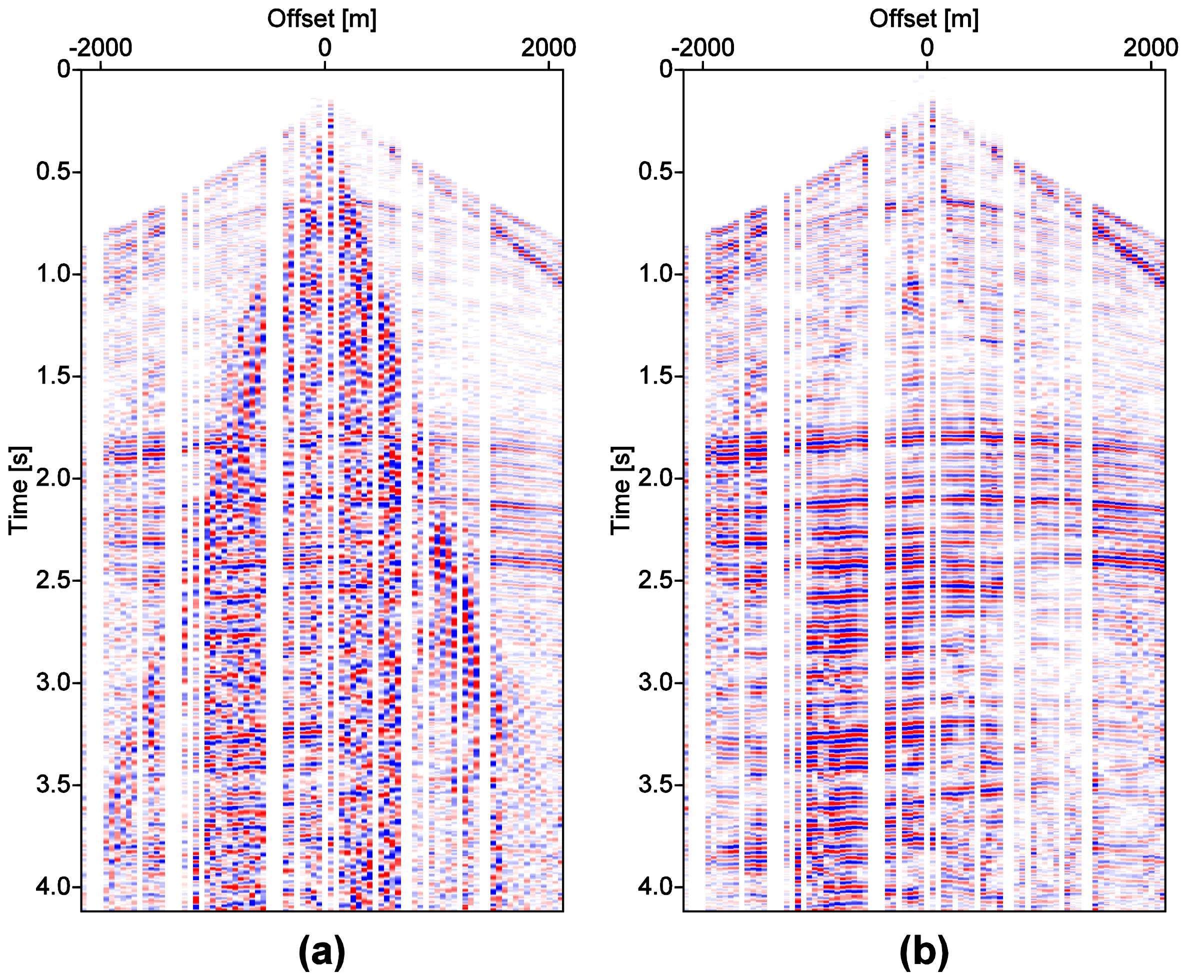

Figure 3 – (a) Randomly decimated shot gather. (b) Data in (a) cleaned by subtracting the noise model constructed using LWD. 22 out of 86 traces were muted.

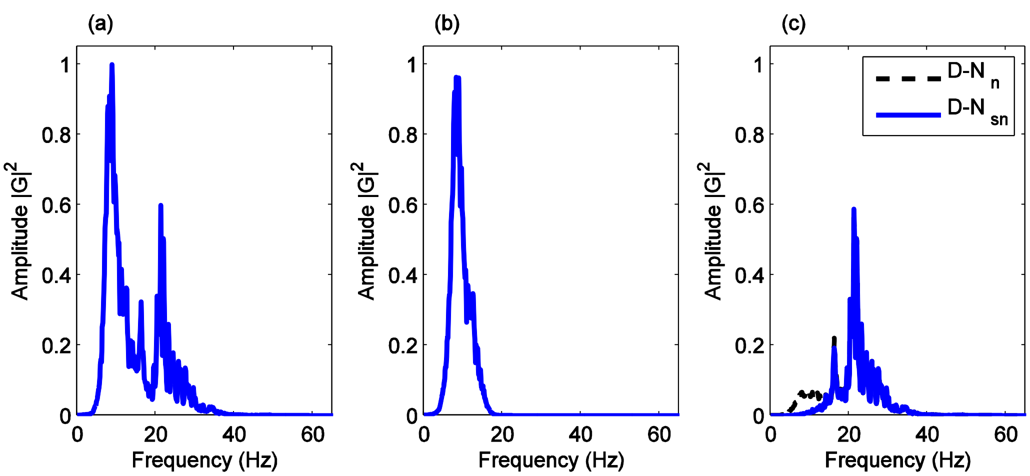

Figure 4 - (a) Amplitude spectrum of the input field data in Figure 3 (a). (b) Amplitude spectrum of ground roll model recovered by LWD, Nn. (c) Amplitude spectra of the clean data in Figure 3 (b). Noise model Nsn is the sum of the low pass filtered residual data and the noise model, Nn. Residual data is defined here as the data captured in neither LWD's signal nor noise model.