Ground Roll Attenuation via SVD and Adaptive Subtraction

Peter Cary*
peter_cary@sensorgeo.com
and
Changjun Zhang
Sensor Geophysical Ltd., Calgary AB, Canada

Summary

Ground roll attenuation is an important step in seismic data processing. We implement a two-step procedure to eliminate ground roll from seismic data. The first step uses singular-value decomposition (SVD) within localized time-space windows to estimate the ground roll and other forms of coherent noise in the data. The second step adaptively subtracts the ground roll estimate from the data. The method can be applied either to single-component or multi-component seismic data.

Introduction

Ground roll, which is also known as a Rayleigh waves, is a persistent form of source-generated noise on land seismic data that obscures reflection signal and degrades overall data quality. Finding an optimal method to attenuate ground roll has long been a goal in seismic data processing (Anstey, 1986). In ideal situations the partical motion of Rayleigh waves is retrograde elliptical and confined to the vertical and inline axes, but ground roll is commonly observed on all three components of multicomponent land data.

Techniques to eliminate noise are commonly developed based on the characteristics of the noise. Ground roll appears as low-velocity, low-frequency and high-amplitude waves which are distributed in fan-shaped zones at near offsets about the source. Traditional filtering methods such as F-K or tau-p filtering can be very effective at attenuating ground roll but they can have limited success because of irregular trace spacing and data aliasing. They also can generate artifacts due to spatial impulse-response smearing. It is therefore desirable to have alternative methods to attenuate ground roll.

Eigenimage filtering with the Karhunen-Loeve transform or singular value decomposition (SVD) is able to avoid many of these sampling and smearing issues (Liu, 1999; Franco and Musaccchio, 2001; Kendall and De Meersman, 2005; Chiu et al., 2007, 2008) . Our algorithm is implemented in two steps. The first step estimates ground roll using SVD from the 1C or 3C data within a limited frequency band with small localized time-space windows. The second step subtracts the estimated noise from the data via time-adaptive filtering (Griffiths et al., 1997). This two-step method tries to optimize ground roll removal while preserving the reflected energy.

Method

The objective is to develop a method to attenuate dispersive, non-stationary and aliased coherent noise in the presence of phase and amplitude perturbations.

Ground roll is dispersive, which means that each frequency travels at a different speed. In order to handle dispersion we bandpass the seismic data within the ground roll window of a shot gather into several frequency bands and process each frequency band separately. The ground roll is then linear along the offset direction and it is straightforward to align, regardless of the spatial sampling of traces. SVD can now be applied to separate the high-amplitude ground roll from the weak underlying reflections which align in a different direction.

If multicomponent receivers have been used, then polarization analysis can be applied to extract elliptically polarized ground roll (Franco and Musacchio, 2001). SVD projects the three-component data to three mutually orthogonal axes. Ideally, high-amplitude, elliptically polarized ground roll requires two of the three components for its description. Polarization filtering can be applied on a single receiver location or on a group of receivers. Theoretically, polarization analysis is most accurate when there is a single wave type present in an analysis window. In practice it is able to separate out the ground roll in the first two components reasonably well from the weaker, underlying signal.

It is not necessary to have multicomponent data in order to apply this two-step ground roll attenuation method. It is possible to apply SVD to a set of neighbouring vertical component traces from regular 1-C geophones and apply a threshold to the number of principal components that are used to construct the noise model. This threshold can be adjusted to preserve the signal as much as posssible.

Ground roll that is estimated by SVD can be further adjusted by means of adaptive filtering. Adaptive deconvolution estimates future values of a seismic trace from its past values (Griffiths, 1977). Adaptive filtering is performed to match the estimated ground roll to the real ground roll in the observed data. It essentially makes small time-varying adjustments to the amplitude and phase of the estimated ground roll in order to better match the real ground roll in the data.

Examples

The method is first illustrated with a 3-C example. Figure 1 shows the results of ground roll attenuation using SVD and adaptive subtraction on the first 1000m of offset of a single 3-C, 3-D shot gather. The top row shows the vertical, radial and transverse components before attenuation, the middle row shows the same data after attenuation, and the bottom row is the difference (the noise removed). The method has been able to remove a large amount of the noise while leaving the weaker reflections underneath the noise largely untouched.

Figure 2 shows the method applied to one-component data. Again there is excellent separation between signal and noise.

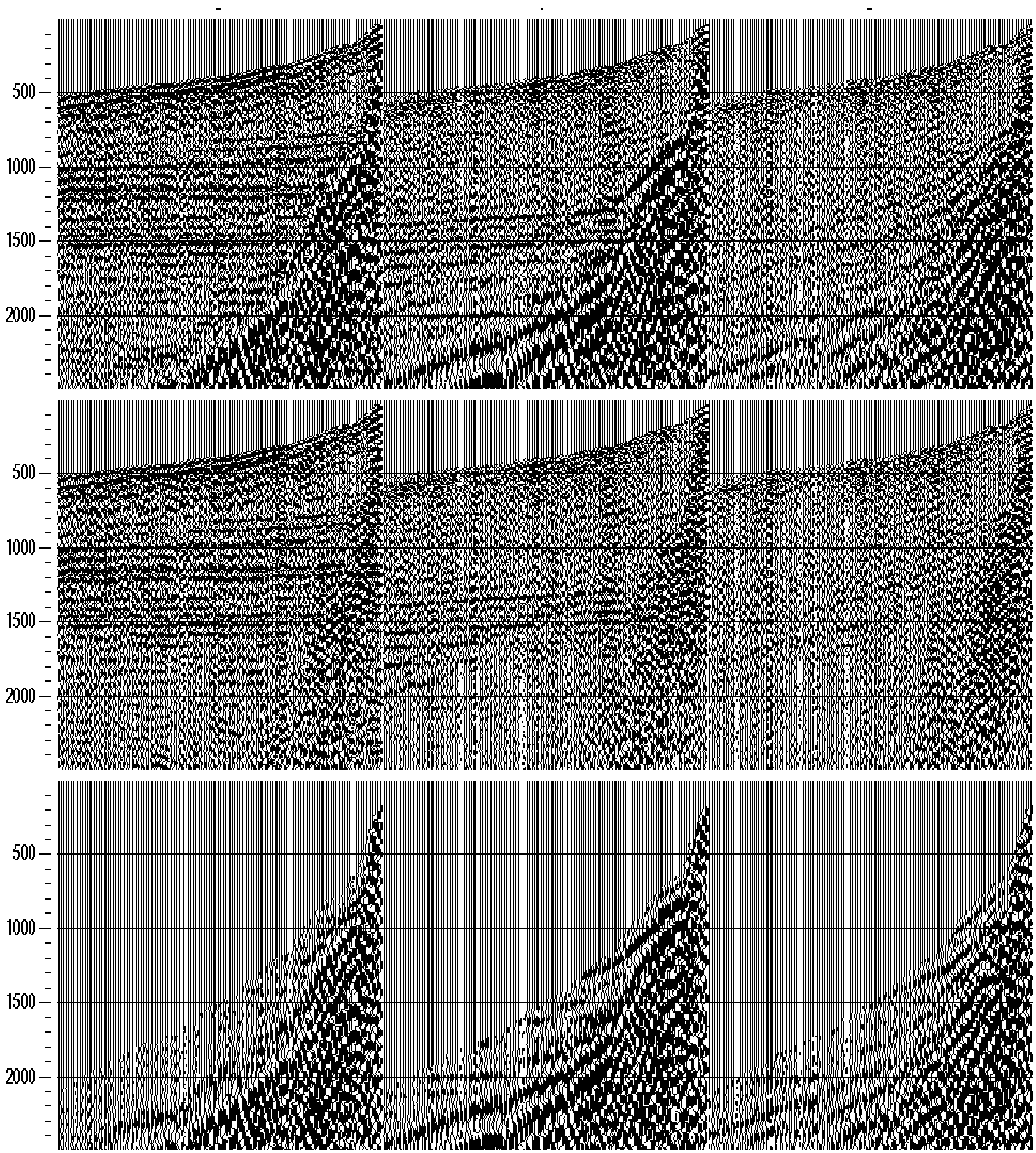

Figure 1: Top row: Vertical, radial and transverse components from a 3-D shot gather. Middle row: After ground roll attenuation using SVD and adaptive subtraction. Bottom row: Noise removed.

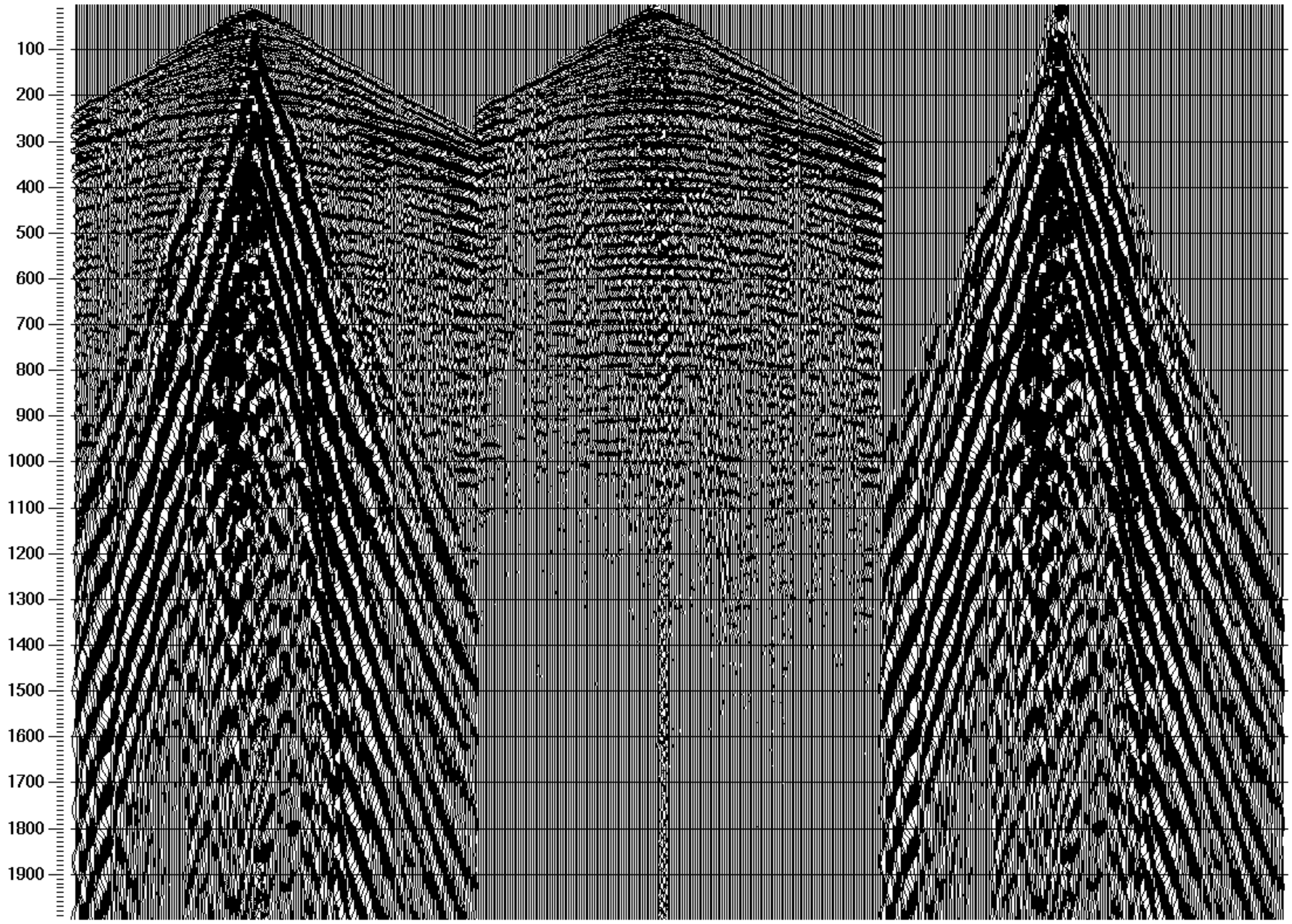

Figure 2: Left: Input 1-C, 2-D shot gather. Middle: After ground roll attenuation. Right: Noise removed.

Conclusions

Separating ground roll from reflections is a difficult task. In a practical manner this goal can be partially achieved through careful extraction of the ground roll from multicomponent or single-component data using SVD and adaptively subtracting it from the original traces. The two-step procedure described here attenuates ground roll effectively from seismic data while preserving the reflections.

References

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