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Quantifying footprint

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Summary

A method is presented to numerically estimate the degree of seismic acquisition footprint in a 3D seismic volume. Operating on time (or depth) slices, the method first constructs digital representations of the source and receiver grids and then these grids are crosscorrrelated with a chosen time slice. For orthogonal source and receiver grids, the procedure is especially simple since only correlation lags orthogonal to the source or receiver lines need be examined. Footprint causes a periodicity in the crosscorrelations whose period is the ratio between the line spacing and the image bin dimension. In a series of examples using real data, it is observed that the grid correlation measurement is much more sensitive than mere visual assessment to detect footprint. This is especially useful for comparing the effectiveness of alternative methods of footprint suppression.

Introduction

A number of methods have been proposed for reducing, or suppressing, footprint. Among these are (1) Reducing the acquisition line spacing (e.g. Hong-jun et al, 2011), (2) Wavenumber filtering of time slices (e.g. Soubaras 2002, Falconer and Marfurt, 2008), (3) Truncated SVD filtering (Al-Bannagi et al. 2005), (4) Geostatistical filtering (Hober et al., 2003) and undoubtedly many more. However, this paper is not about presenting a new technique for footprint suppression, but rather to suggest a simple and objective method to quantify the level of footprint in a dataset and to objectively evaluate the degree of suppression achieved by a given method. Essentially the proposed quantification involves constructing digital representations of the acquisition grids and measuring the crosscorrelation between these digital grids and time slices from a seismic survey.

Theory and/or Method

I will present the method and some basic results by way on an illustrative example using a 3D survey conducted by Devon Energy. Shown in Figure 1 is a time slice from this survey which exhibits west-east streaking that was judged to be footprint. In this case, the receiver lines are oriented west-east while the source lines are north-south. The image shown is from migrated data with a bin size of 82.5x82.5 ft. The spacing between receiver lines was 10 times the bin size or 825 ft. and the source lines were similarly spaced. The time slice in question can be regarded as a matrix having 747 rows (the number of inlines) and 550 columns (the number of crosslines) where there is one matrix sample for each 82.5 ft2 bin in the image. The construction of digital representations of the receiver grid therefore involves constructing a similar sized matrix which is zero everywhere except at receiver locations where it takes the value 1. The source grid is similarly constructed. Rather than make these grids perfectly sharp 1/0 constructions, I then applied a gentle isotropic wavenumber filter that slightly fuzzes the amplitude transition.

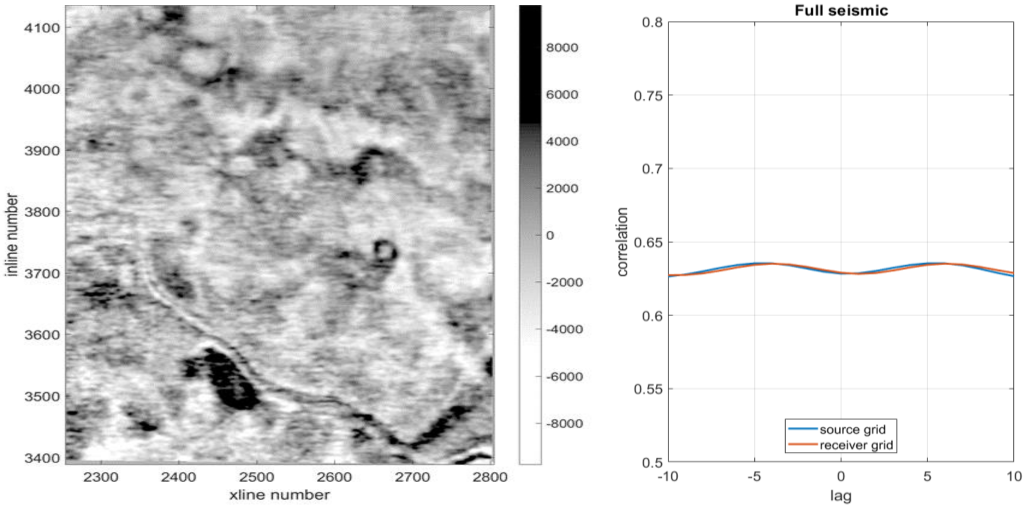


Figure 1: (left) A time slice from the example survey showing obvious east-west (right-left) streaking. The receiver lines were oriented east-west (left-right) and the source lines north-south. (right) The result of the grid correlations described in the text. The acquisition grids were crosscorrelated in 2D with the absolute value of the time slice.

In the construction of these grids, the exact locations of source and receiver are not important and not used. What is used is the spacing between source and receiver lines which was carefully constructed to be 825 ft. These represent nominal grids and no attempt has been made to honor departures from ideal grids that occurred during actual acquisition due to cultural obstacles and the like.

The method proposed here is to crosscorrelate the source and receiver grids with the time slice. Given the symmetry of the source grid, only correlation lags in the xline direction need to be calculated and, similarly, only inline lags are required for the receiver grid. Furthermore, these grids have a periodicity of 10 in the direction orthogonal to their symmetry and so it is sufficient to examine lags from -10 to +10 in each case. At some lag, k, the source grid will align with the actual grid and then will align again with ± 10 lags from the lag k. What we are looking for is a periodicity of 10 in these computed correlations as an indication of footprint.

I have found it most revealing to crosscorrelate the grids with the absolute value of the time slice rather than the slice itself. Assume for arguments sake that the footprint is imposed on the time slice as a multiplication of the grid and the slice. The slice will have both positive and negative values and the multiplication by the grid will make the positives more positive and the negatives more negative. In the crosscorrelation, the values that align with the grid are selected and summed and thus the positives and negatives will tend to cancel. Using the absolute value of the time slice avoids this effect. Numerical experimentation with this real dataset has confirmed a much stronger footprint signal is seen with the absolute value technique.

Figure 1 also shows the result of the grid correlation procedure. There is a clear periodicity of 10 in both correlation functions indicating the presence of both receiver and source footprint. The receiver-line footprint was visually anticipated, but the source-line footprint was not (at least to my eye). This is a first indication of the value of objective measures. They may well detect more than does the eye.

Examples

Figure 2 shows a simple footprint suppression technique using SVD (singular-value decomposition) to separate the time slice into parts Gross and Detail and then applying wavenumber low-pass filters to each using potentially different filter parameters. A very simple wavenumber filter is employed here which consists of multiplying the time slice in the wavenumber by a 2D Gaussian whose standard deviation is σ. Expressed as a fraction of the Nyquist, smaller σ values indicate stronger filtering. In this case the Gross part was more strongly filtered than the detail. Figure 3 shows the result of grid correlation measures on the size panels of Figure 2. A first observation is that both gross and detail show strong footprint and the wavenumber filtering has only suppressed the footprint in gross.

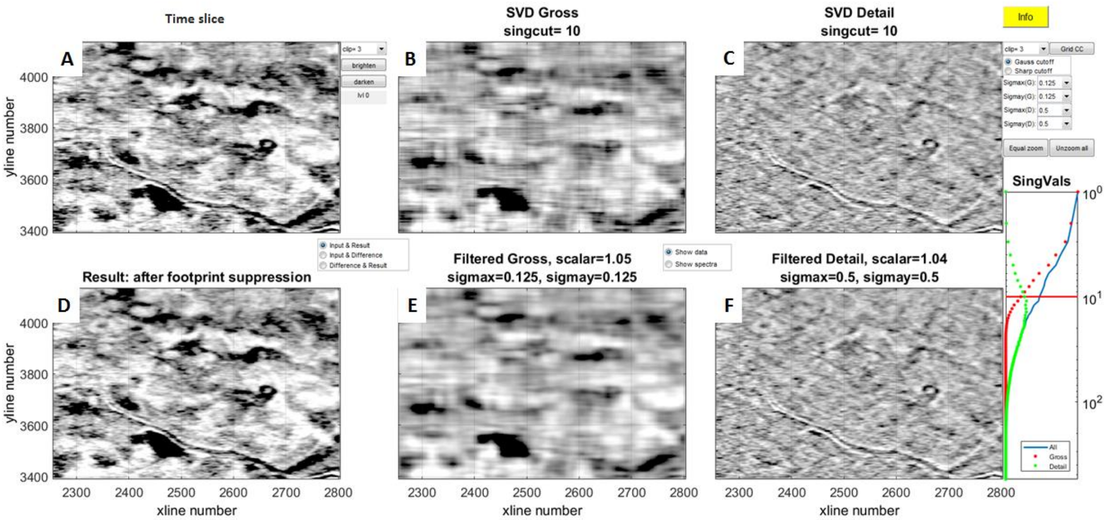

clip= 3
○ Gauss cutoff (selected) ●
Sigmax(G): 0.125
Sigmay(G): 0.125
Sigmax(D): 0.5
Sigmay(D): 0.5

Figure 2. Illustrating the results of a particular wavenumber filter on the time slice of Figure 1. A, B, and C are the SVD separation of the time slice before wavenumber filtering while D, E, and F are after. In this case, the gross part was filtered with standard deviation $\sigma = 0.125$ which is moderately severe. The detail part was lightly filtered with $\sigma = 0.5$.

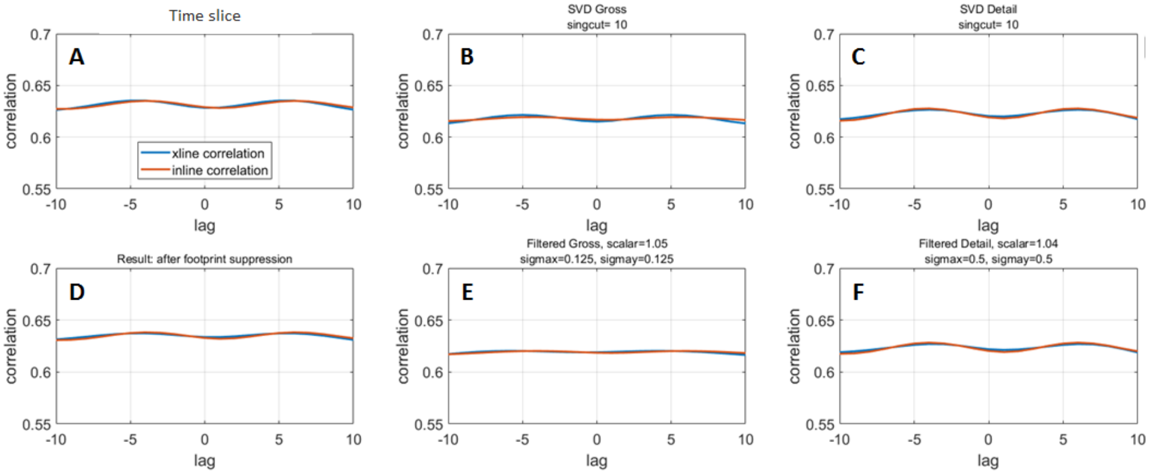
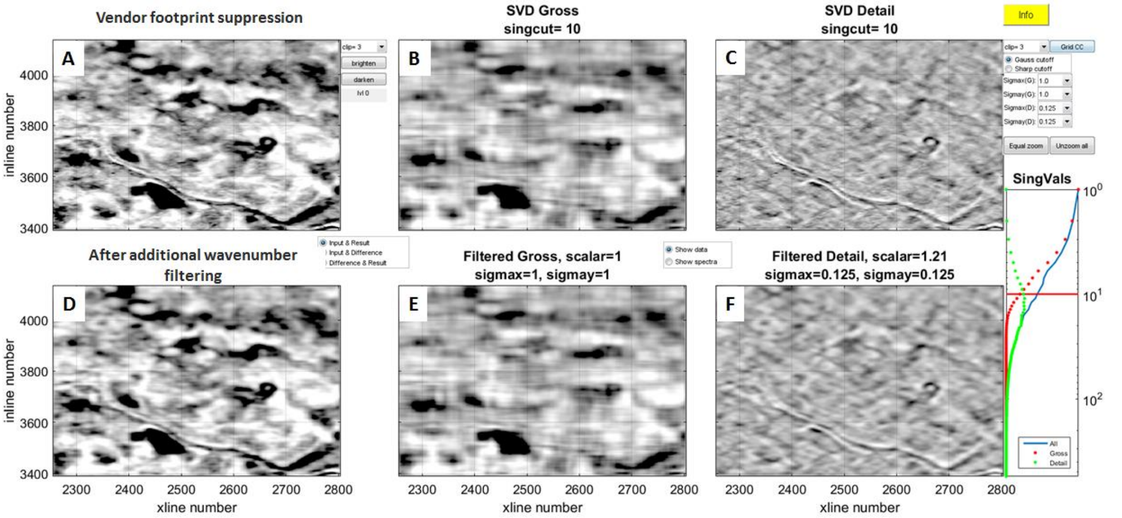


Figure 3. Grid correlations for the six panels of Figure 2. It is apparent that there is strong footprint in both gross and detail and the wavenumber filtering has suppressed it in the gross part.

A second example is shown in Figure 4. In this case the result in panel A is after footprint suppression by a vendor-supplied geostatistical process, and panels B and C show an SVD separation on this result. Panels D, E, and F show a subsequent gentle wavenumber filter applied to the vendor result. The grid correlations for these six panels are shown in Figure 5. From these it can be inferred that the vendor has reduced the footprint somewhat in the gross portion but less so in the detail. In the subsequent wavenumber filtering, further footprint suppression was achieved but at the expense of some loss of detail.



clip= 3

● Gauss cutoff
○ Sharp cutoff

Sigmax(G): 1.0
Sigmay(G): 1.0
Sigmax(D): 0.125
Sigmay(D): 0.125

Figure 4. Here is an analysis of footprint suppression done on the time slice of Figure 1 by a vendor-supplied geostatistical filtering technique. Panel A shows the vendor result while panels B and C are its separation into gross and detail. Panels D, E, and F show the application of a further wavenumber filter to the vendor result. The next figure shows the grid correlations.

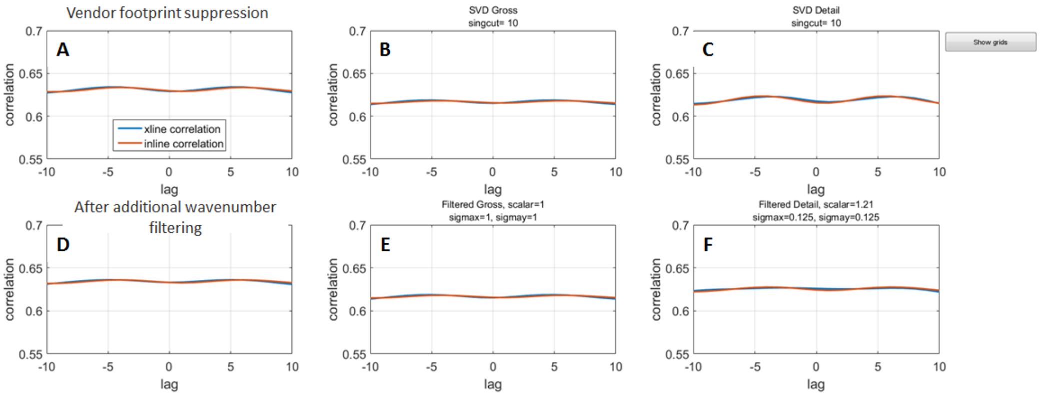


Figure 5. Here are grid correlations of the six panels of Figure 4. It is apparent that the geostatistical method has done some suppression on the gross part but very little on the detail.

Conclusions

This paper has proposed an objective method of assessing the quality of the suppression. This method uses 2D crosscorrelations between the seismic time slices and numerical representations of the source and receiver acquisition grids. Footprint is indicated by the observation of a periodicity in these crosscorrelations. This technique then gives an objective measure that can complement the more common visual assessment and difference plotting.

Acknowledgements

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References

Al-Bannagi, M., K. Fang, P. G. Kelamis, and G. S. Douglass, 2005, Acquisition footprint suppression via the truncated SVD technique: Case studies from Saudi Arabia: The Leading Edge, 24, 832–834.

Falconer, S., and K. J. Marfurt, 2008, Attribute-driven footprint suppression, 78th Annual International Meeting, SEG, Expanded Abstracts.

Hober, H., T. Coleou, D. Le Meur, E. Angerer, P. Lanfranchi, and D. Lecerf, 2003, On the use of geostatistical filtering techniques in seismic processing, SEG international Exposition and Annual Meeting, Expanded Abstracts.

Hong-jun, Z., W. Lin, and W. Jun, 2011, Seismic Data Processing Methods to Suppress the Acquisition Footprint, SPG/SEG International Geophysical Conference, Expanded Abstracts.

Soubaras, R., 2002, Attenuation of acquisition footprint for non-orthogonal 3D geometries, SEG International Exposition and 72nd Annual Meeting, Expanded Abstracts.