Use of Simple 2-D Filters to Reduce Footprint Noise in Seismic Data

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Summary

The acquisition footprint noise is commonly present in 3-D seismic data and obscures geological information needed for accurate mapping and prospect development. Ideally, the footprint noise should be removed in the processing step using one of many deterministic techniques discussed in the literature. However, this is rarely done because it takes an effort to understand the nature of the footprint noise which varies with the acquisition geometry and depth of the seismic data. Therefore, many times the interpreters have to pretend that the noise doesn't exist and proceed with geological interpretation in the presence of noise. We show that by using simple 2-D filters in the interpretation process, the interpreter can considerably enhance the quality of the seismic data. Moreover, the interpreter has complete control over how much noise should be filtered without adversely affecting the geological interpretation.

1. Introduction

The final stacked and migrated 3D seismic dataset available to the seismic interpreter is often replete with regular variations in seismic attributes such as amplitude and phase. These variations have nothing to do with the geology and are the result of acquisition design, processing problems, or a combination of both. The footprints are commonly seen as amplitude stripes in time slices produced from a seismic data volume. Since a typical footprint pattern seems to mimic the acquisition geometry, the term "acquisition footprint" is commonly used.

However, we propose a general term called "footprint noise" because the term "acquisition footprint" is misleading due to its explicit reference to acquisition as the sole reason for footprints in seismic data. We define footprint noise in seismic data as variations in a seismic attribute which are not related to the variations in geology. These variations may be apparent along a horizon in a seismic cross section or a time slice of seismic data.

Drummond et al. (2000) discuss two types of footprints. One type of footprints can be caused by coherent noise whose pattern is related to the data acquisition geometry and field parameters such as source and receiver line intervals. The bin-to-bin fold, offset and azimuthal variation fall into this type of footprint problem. The other type of footprint is caused by signal processing problems such as the use of incorrect normal move out (NMO) velocities, amplitude-versus-offset (AVO) effects, etc. Hill et al. (1999) provide modeling examples that illustrate the role seismic processing plays in the appearance of footprint noise in seismic data.

The footprint noise in seismic data is a nuisance to the interpreter. In addition, the amplitude anomalies caused by footprints affect the interpretation of seismic data. Marfurt et al. (1995, 1998) discuss the effect footprint noise has on the mapping of seismic attributes such as seismic coherency. During the last few years there has been an exponential increase in the number of attributes that can be mapped from seismic data for geological inferences (Brown, 1999). Therefore, it is important to eliminate or at the least suppress the footprint noise in data so that the data is not only easier to interpret but also leads to a better interpretation.

2. Nature of footprint noise

An understanding of the nature of foot print noise in seismic data is essential before methods can be devised to suppress it. Figure 1 shows the time slice at 1020 ms extracted

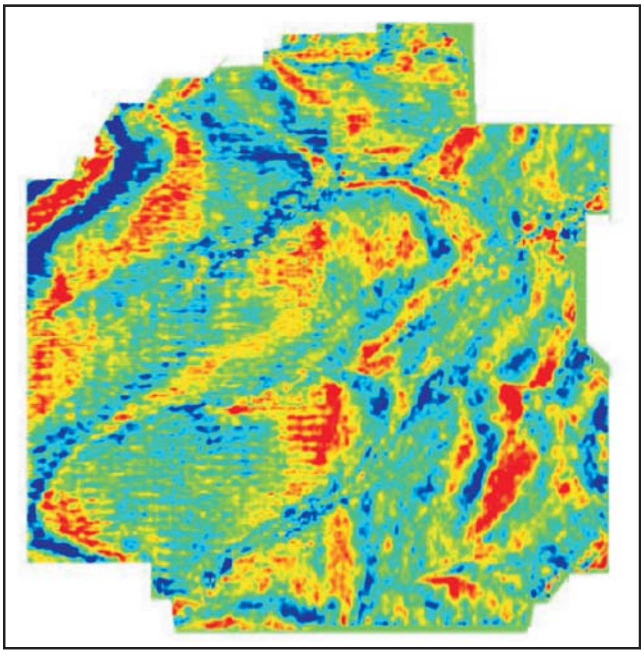

Fig-1. Seismic time slice at 1020 ms generated from a 3D volume of data acquired in south-central Texas. The footprint noise in the form of vertical and horizontal stripes is apparent in the left half of the time slice.

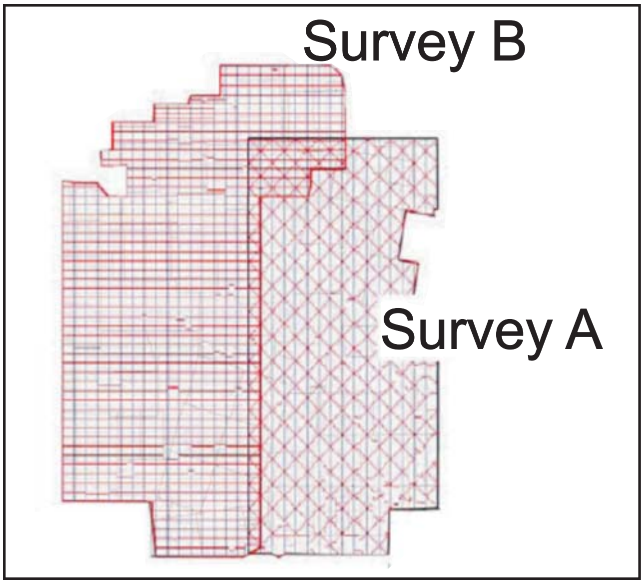

Fig-2. Two different acquisition geometries used in acquiring the seismic data in south-central Texas. Survey A: zigzag design. Survey B: orthogonal design.

from a 3D data set acquired in south-central Texas. The data was acquired with two different survey designs. In Figure 2, the eastern half of the survey (dataset A) employed a zigzag pattern of sources between receiver lines. The western half of the survey (dataset B) was acquired with an orthogonal survey design where the source lines were orthogonal to the receiver lines. The horizontal and vertical stripes in the western half of the survey are quite evident in the time slice shown in Figure 1. However, there is very little footprint noise in the eastern half of the survey. Therefore, the survey geometry has a marked influence on the footprint noise. The

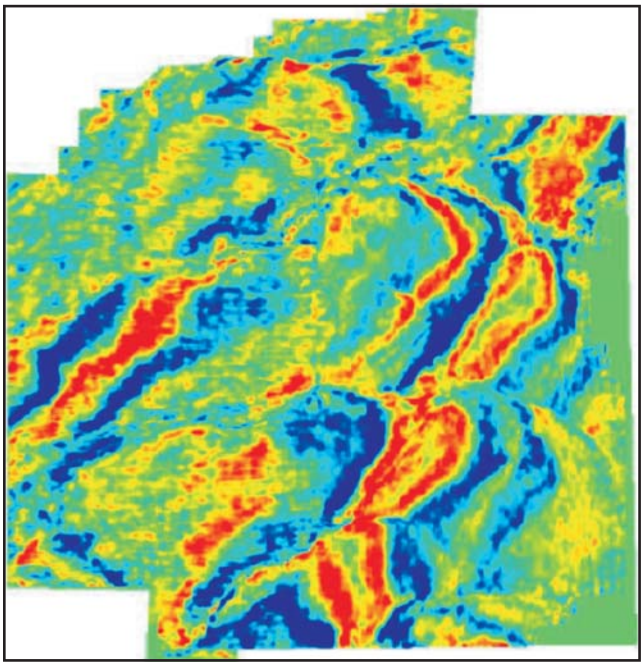

Fig-3. Seismic time slice at 1200 ms shows vertical stripes in the right half of the data. Some footprint noise is present in the left half of the time slice but is not as severe as in the 1020 ms time slice shown in Figure 1.

nature of the stripes in the seismic time slice are not necessarily orthogonal as seen in the time slice at 1020 ms, but can display different patterns depending on the survey geometry and the wave field being sampled.

Figure 3 shows the time slice at 1200 ms. There is some horizontal striping in dataset B, but in general the footprint noise is much more subdued in comparison to the time slice at 1020 ms. However, dataset A shows some vertical striping which was not apparent in the time slice at 1020 ms. The data show that for orthogonal acquisition design (survey B) the footprint noise is more severe in the shallow portion of the data and decreases with depth. However, for zigzag acquisition design, the footprint noise increases with depth. A possible explanation is that the amplitude variation with offset for events at different times is also different. Therefore, in addition to the effect of variable bin-to-bin fold, the AVO effect influences the pattern of footprint at different times. Our experience is that it is difficult to generalize the behaviour of footprint noise in seismic data.

A notable feature of footprint noise is that there is an appearance of periodicity to it regardless of the directivity and pattern of noise in a time slice. Therefore, it may be possible to reduce its effect on the interpretation of seismic data. The past efforts in this area can be divided into two categories. In one category are techniques that seek to reduce the effect of variability in bin-to-bin fold, offset distribution, and azimuthal coverage by interpolation and extrapolation of the wave field (Chiu and Stolt, 2002). In another category are techniques that employ some type of image enhancement technique by filtering (Gulunay, 1999; Chopra and Larsen, 2000; Drummond et al., 2000; Karagul and Crawford, 2003; Soubaras, 2002; Al-Bannagi and others, 2004). The method presented here utilizes image filtering by providing control to the seismic interpreter to quickly and efficiently design an appropriate filter to reduce the effect of footprint noise in the horizon or time slices.

3. Simple 2-D Filtering Solutions

The presence of footprint noise in seismic data is generally not known until the interpreter begins to examine the data in 2-D or creates horizon or time slices from the 3-D volume. At that point, the quickest and easiest solution is to employ a standard suite of applications available on a workstation. This could be a seismic interpretation workstation or an unrelated software package that provides the capability to filter data with K_x-K_y filters. One such application is the ERMapper† ® software which is used extensively in remote sensing for image enhancement. Version 5.5 of the ERMapper ® software used in the examples shown here has a very flexible implementation of the Fast Fourier Transformation (FFT). Therefore, an image of a time slice or a flattened horizon mapped by the interpreter can be

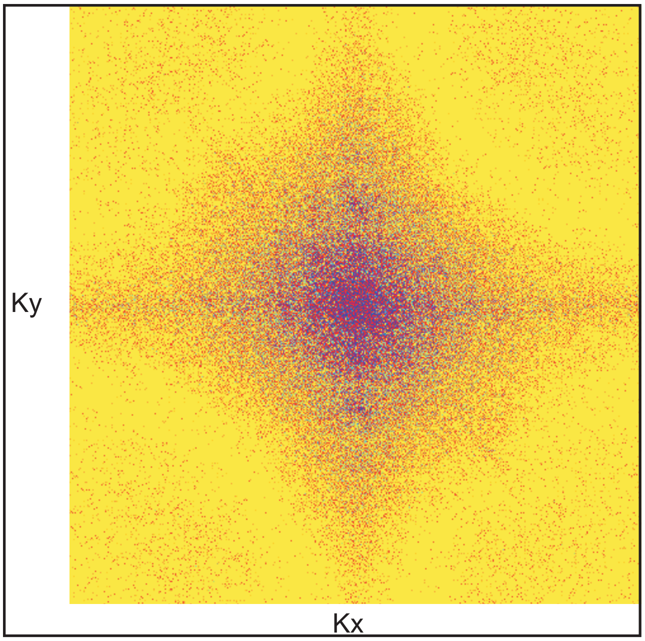

Fig-4. Two-dimensional FFT of the time slice at 1020 ms. High frequencies along the axes correspond to the footprint noise i.e. vertical and horizontal stripes in the dataset.

transformed from the spatial to the K_x-K_y domain. A filter can be designed to filter out the unwanted noise in this domain and the data transformed back to the spatial domain for interpretation.

† Earth Resource Mapping Inc.

Figure 4 shows the two-dimensional FFT of the time slice with footprint noise shown in Figure 1. Since the stripes due to the footprint in this data are mainly horizontal and vertical, they lie in a narrow fan shaped region around the axes of the K_x-K_y plot. The noise stripes are necessarily high frequency as compared to the geological variations that are inherently low frequency in character. Therefore, we can safely filter the high frequencies from the FFT image by designing a low-pass filter. The filtered image in the frequency domain shows a circular band of frequencies around the origin that represent the filtered image (Figure 5). Now the filtered image in the frequency domain can be transformed back to the spatial domain.

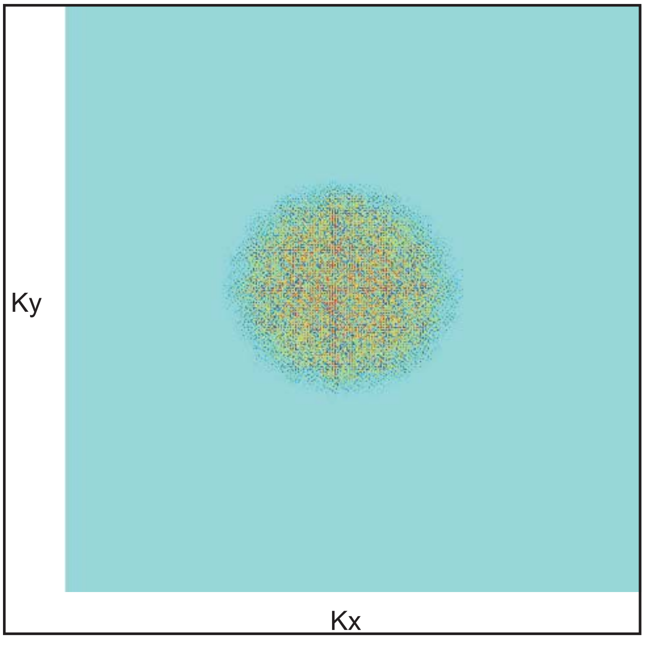

Fig-5. A filtered image of the time slice at 1020 ms in the frequency domain obtained after removing the high frequencies with a low-pass filter.

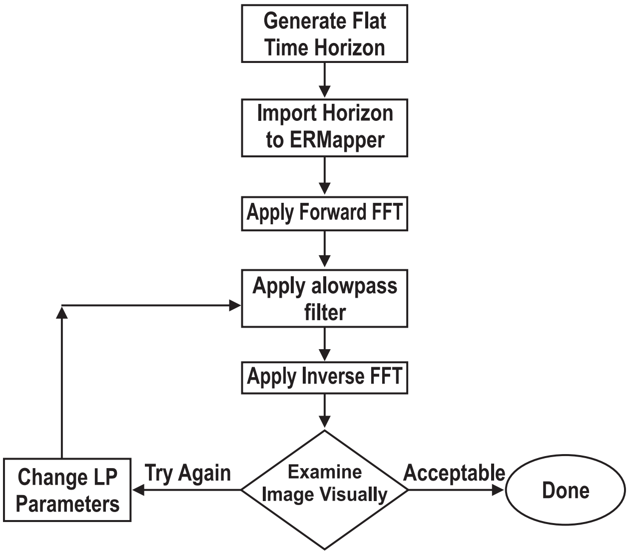

Fig-6. Flowchart showing the step-by-step procedure in removing the footprint noise from a horizon or time slice image.

The flowchart in Figure 6 shows the procedure for footprint removal in the seismic horizon or time slice data. A comparison of the unfiltered and filtered image in Figure 7 shows that the footprint noise is considerably reduced in the filtered version. It is important to note here that the interpreter has full control over the design of the filter. A more severe filter may adversely affect the geological interpretation. Unless the seismic processor and the interpreter work closely together to design deterministic filters to remove footprint noise in the processing step, the interpreter is left with full control over how much post-stack

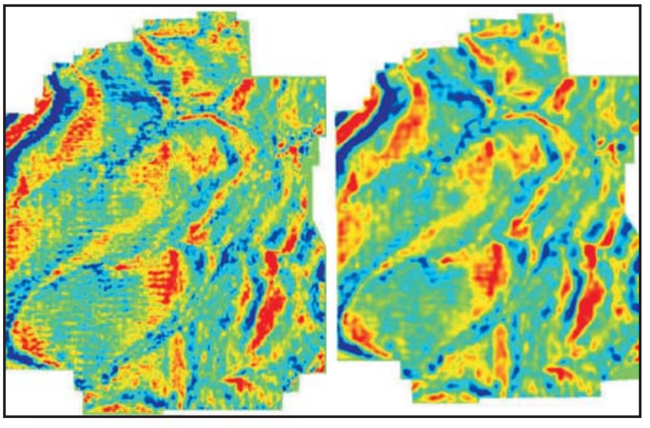

Fig-7. A comparison of the original time slice (image on the left) with the filtered time slice (image on the right). The filtered time slice shows much reduced footprint noise.

filtering is adequate to remove the noise. However, there are software tools available to accomplish this task efficiently.

4. Conclusions

A quick and easy solution such as the one presented in this paper provides a method for reducing footprint noise in seismic data. Fast Fourier Transform of time slices gives the interpreter control in deciding how much spatial filtering is appropriate for a given dataset. The method presented is fast and thus very cost effective in reducing noise in data during the interpretation process.

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References

Al-Bannayi, M.S., Fang, K., Kelamis, P.G., and Douglas, G.S., 2004, Acquisition footprint suppression via the truncated SVD technique, SEG 74th Annual Meeting Expanded Abstracts, 1957-1960.

Brown, A.R., 1999, Interpretation of Three-Dimensional Seismic Data, 5th Edition, AAPG Memoir 42, 514 pp.

Chiu, S.K. and Stolt, R., 2002, Application of 3-D data mapping - azimuth moveout and acquisition-footprint reduction, SEG 72nd Annual Meeting Expanded Abstracts, 2134-2137.

Chopra, S. and Larsen, G., 2000, Acquisition footprint - its detection and removal, CSEG Recorder, October 2000, 16-20.

Drummond, J.M.; Budd, Arthur J.L. and Ryan, J.W., 2000, Adapting to noisy 3D data - attenuating the acquisition footprint, SEG 70th Annual Meeting Expanded Abstracts, 9-12.

Gulunay, N., 1999, Acquisition geometry footprints removal, SEG 69th Annual Meeting Expanded Abstracts, 637-640.

Hill, S.; Shultz, M.; and Brewer, J., 1999, Acquisition footprint and fold-of-stack plots, The Leading Edge, v., no. , 686-695.

Karagul, A. and Crawford, R., 2003, Use of recent advances in 3D land processing: a case history from the Pakistan Badin area, EAGE 65th International Meeting Expanded Abstracts, 93-96.

Marfurt, K.J.; Scheet, R.M.; Sharp, J.A.; Cain, G.J. and Harper, M.G., 1995, Suppression of the acquisition footprint for seismic sequence attribute mapping, SEG 65th Annual Meeting Expanded Abstracts, 949-952.

Marfurt, K.J.; Scheet, R.M.; Sharp, J.A., and Harper, M.G., 1998, Suppression of the acquisition footprint for seismic sequence attribute mapping, Geophysics, v. 63, no. 3, 1024-1035.

Soubaras, R., 2002, Attenuation of acquisition footprint for non-orthogonal 3D geometries, SEG 72nd Annual Meeting Expanded Abstracts, 2142-2145.

Points-to-ponder-I

In this forum we invite authors to submit thought provoking questions which have short answers and which bring out some important issues in the theory or practice of exploration geophysics. The questions should be submitted, preferably, along with their answers; however, that is not mandatory and the editorial board will make efforts to find correct answers. Selected questions will be published with their answers.

1. Predictive deconvolution for suppression of multiples does not work as effectively in time-offset domain as in tau- p domain. Why?
2. Presence of AVO and bright amplitude anomaly in a prospect constitute **sufficient** condition for presence of hydrocarbons. True or False? Comment.
3. Presence of AVO anomaly a **necessary** condition for presence of hydrocarbons. True or False? Comment.
4. In a deep water sub-marine fan system, thick sands with gaseous hydrocarbons were expected based on amplitude study of seismic data. Wire-line electro logs in an exploratory well showed a thick 60 meters sand pack within which two intervals about 5-8 meter thick exhibited high gamma, relatively lower resistivity (5 ohms-meter compared to 20 ohms-meter for the rest of the pack which was interpreted to be gas charged sands on the basis of logs), and clear separation between neutron porosity and density logs. As per conventional interpretation of the logs, it was apprehended that these intervals would be shale. On the other hand, pressure studies indicated hydrodynamic continuity across these intervals. Subsequent coring and sedimentological analysis showed that the formation in these intervals were not shale, but silty sands with certain minerals which were responsible for the anomalous “shale-effect”.
   What could be a possible mineral composition of these sands which would explain the above features of the logs?
5. What is the difference between Fermat’s principle and Snell’s law?

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Answers on page 35