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Prestack Trace Interpolation: Comparison of Different Algorithms and Data Domains

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Summary

Because of environmental restrictions and financial constraint, 3D seismic data are almost always acquired in geometries far sparser than what many processing algorithms require, which compromises the quality of seismic images and attributes. Prestack trace interpolation is a practical remedy to make the less ideal data satisfy the requirements of processing algorithms. A good interpolation algorithm should meet at least the following two criteria: 1. no damage to geological structures; 2. no damage to AVO responses and anisotropic information (if there is any). There are many algorithms of interpolation in this industry, such as MWNI, POCS, ALFT and ASFT, to name a few. On the organization of input data, it may be in shot/receiver order, or CMP order. There are two popular domains of interpolation in CMP order, conventional **C**ommon **O**ffset-**A**zimuth (COA) domain, and **C**ommon **O**ffset **V**ector (COV) domain. This paper compares two algorithms, MWNI and ASFT, in both COA and COV domains with a field dataset, and presents the pros and cons of the different algorithms and data domains.

Introduction

During the past decade, prestack trace interpolation became widely used for sparsely sampled land seismic data. Due to the environment restriction and financial constraint, 3D land seimsic data are almost always acquired in the geometries far sparser than what many processing algorithms require, which compromises the quality of the final images. To remedy the less ideal dataset, prestack trace interpolation is a tool to make the dataset satisfy the requirements of the processing algorithms. A good interpolation algorithm should at least meet these two criteria: 1. no damage to geological structures; 2. no damage to AVO responses and anisotropic information (if there is any). An example showing the benefit of interpolation is in Figures 1 and 2. Figure 1 is a time slice of the prestack migration without interpolation, and Figure 2 is the correspondent time slice with prestack trace interpolation. The migration noise is eliminated and structures are sharper in Figure 2, compared to Figure 1.

Many interpolation algorithms are available in the industry, in the paper, two of them, ASFT (Guo et al, 2015) and MWNI (Liu and Sacchi, 2004), are presented and their outputs are compared, in both **C**ommon **O**ffset-**A**zimuth (COA) and **C**ommon **O**ffset **V**ector (COV) domains (Cary, 1999).

Theory

Both ASFT and MWNI are Fourier Transform based algorithms, which in general try to reconstruct the wavefield by solving the best estimated Fourier coefficients:

$$F(k) = \sum \mathrm{f(x)} e^{-2\pi \mathrm{i} <\mathrm{k,x}>} \qquad (1)$$

Where x and k both are 4D vectors. x represents the trace location in 4D spatial domain, while k represents the location of a particular Fourier coefficient in 4D wave number domain. <> is the operator of inner product.

The key differentiator of ASFT versus MWNI is that for ASFT, x and k do not have to be at the grid points, in other words, both x and k can be any arbitrary numbers, either rational or irrational. For MWNI, x and k must be at the grid point in spatial and wave number domains, in other words, they must be discrete with even increment. Therefore, the advantage of ASFT is that the accuracy of the trace positions and wave number components are well maintained, while MWNI snaps the trace location (in 4D space) to the grid points which will somehow smear geological structures and AVO (AVAZ) information.

The input data to interpolation algorithms can be in various domains, two popularly used domains are: (1) Common Offset-Azimuth (COA) and (2) common Offset Vector (COV). Figure 3 shows an example of interpolated CMP gather in COA and COV domains with ASFT interpolation.

Examples

A field dataset with an orthogonal acquisition geometry from the Western Canadian Sedimentary Basin was used for the tests. From the test results, ASFT outputs provide better spatial resolution compared to MWNI outputs, because ASFT does not compromise the trace locations therefore no smearing of geological structures. In term of data domains, COA and COV yielded comparable results at deep sections, but at the shallow sections, COA did better job to remove the acquisition foot prints, compared to COV.

Conclusions

Because ASFT honors the true acquisition locations, and true offsets and azimuths (or true offset vectors, if COV is used) of the input traces without snapping traces into the grid points, it provides sharper images and preserves structures better than MWNI. At the deep sections, applying interpolation in both COA and COV domains provide comparable result, but at the shallow sections, COA works better than COV.

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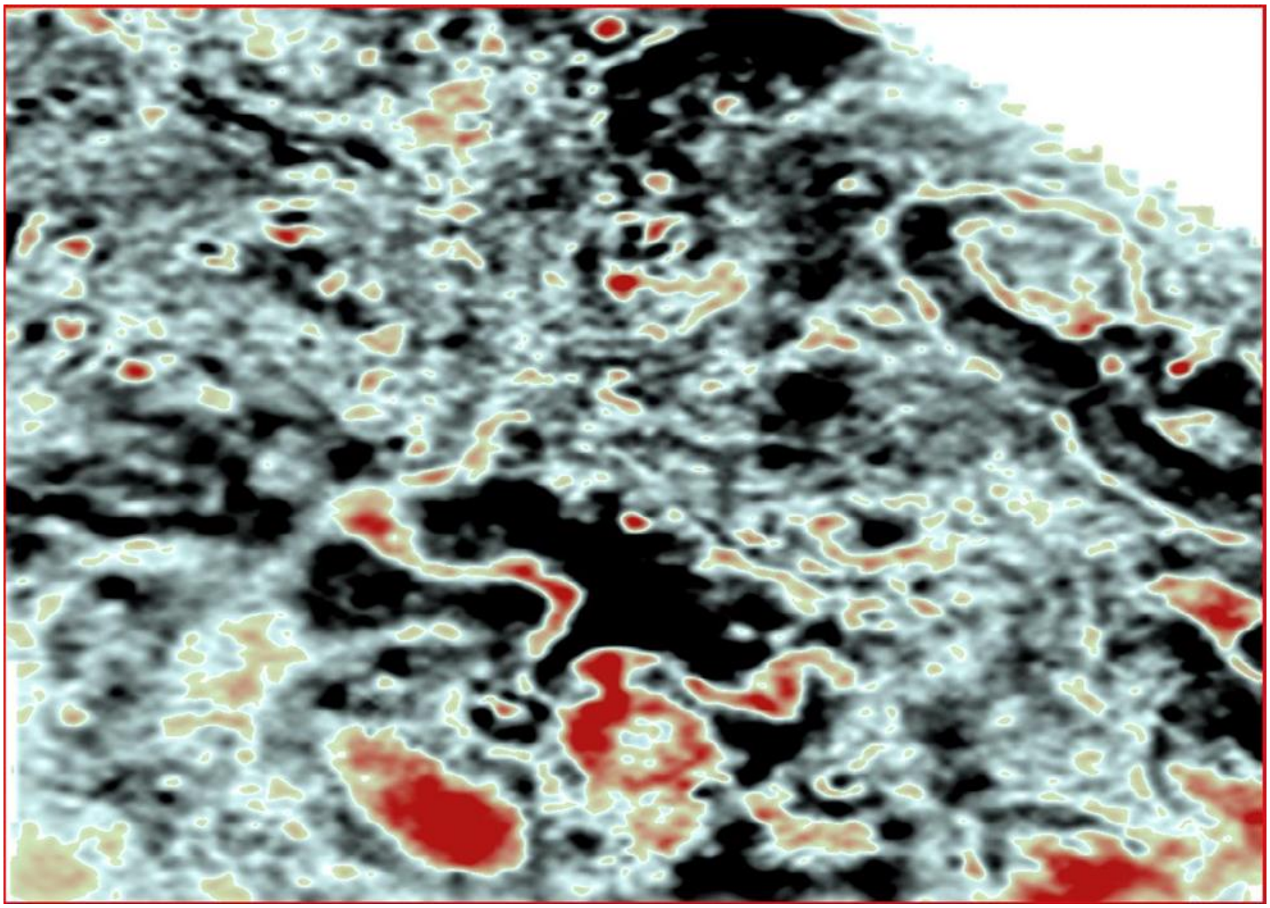

Figure 1, a time slice of prestack migration without interpolation.

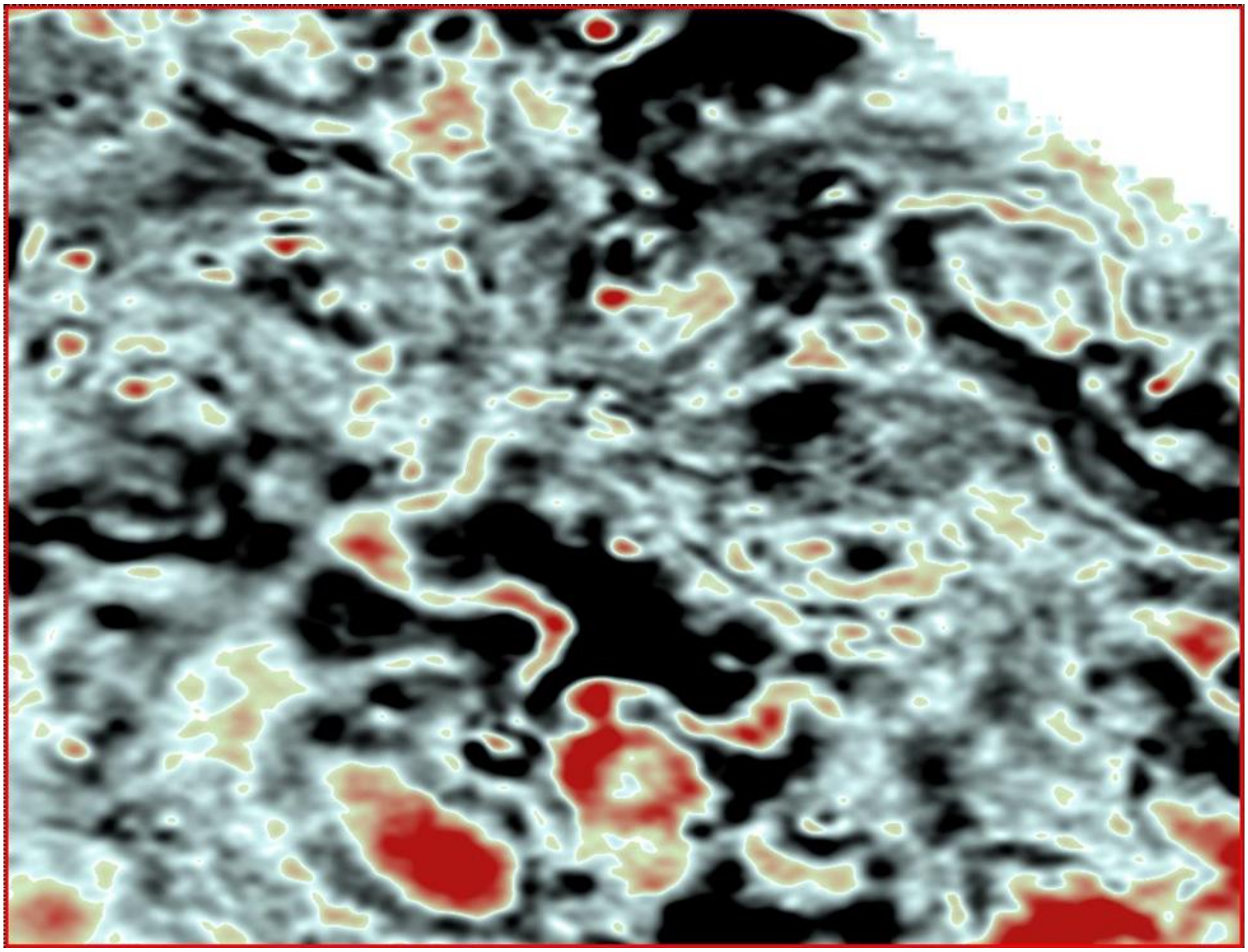

Figure 2, the correspondent time slice as Figure 1, prestack migration with interpolation. Migration noise is eliminated and the structures are sharper.

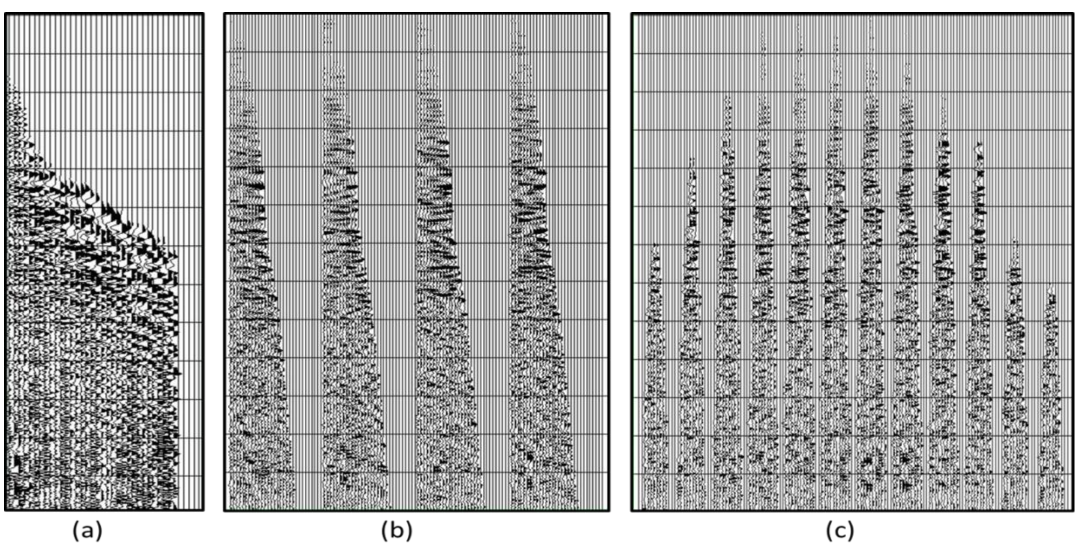

Figure 3, (a) input gather to ASFT interpolation; (b) COA gather from ASFT interpolation; (c) COV gather from ASFT interpolation.