Can interpolation help reduce acquisition costs? A case study

Ye Zheng*, Geo-X Exploration Services Inc., Calgary, AB, Canada
ye.zheng@geo-x.ca
and
Balazs Nemeth, Christian Escalante, BHP Billiton, Saskatoon, SK, Canada
Andrea Crook, Keith Millis, OptiSeis Solutions Ltd., Calgary, AB, Canada
Laurie Ross, Geo-X Exploration Services Inc., Calgary, AB, Canada.

Summary

Prestack trace interpolation (5D interpolation) is widely used in seismic data processing recently to regularize spatial sampling and recover missing traces. There are many successful cases of interpolation helping improve prestack migration images, stabilize AVAZ analysis, and distinguish and attenuate short period multiples.

It is a hot topic if interpolation can help reduce acquisition costs. In this study, different decimation tests of a typical orthogonal land seismic survey in combination with 5D interpolation were conducted to investigate the ability of recovering missing data by interpolation. The test results show that 5D interpolation provides an opportunity to reduce acquisition cost with thoughtful design. The results also show that 5D interpolation can eliminate acquisition footprints and increase signal-to-noise ratio of final images.

Introduction

Prestack trace interpolation in 5D domain has been widely included in seismic processing sequences to regularize spatial sampling for recovering missing traces while helping improve the quality of subsequent processes, such as prestack migration, AVAZ analysis (Zheng, et al, 2011) and multiple attenuation (Hunt, et al, 2011). One question often asked in the seismic industry is “Can interpolation help reduce acquisition cost?” On one hand, since interpolation has the capability to reconstruct the wavefield from incompletely sampled data; it provides the opportunity for recording less data in the field and recover/fill missing data by interpolation. On the other hand, if the acquisition geometry is too sparse, information from some geological features may not be collected in the field data so that the information lost in the field cannot be recovered by interpolation, since interpolation won’t create information. The purpose of this study is to understand what kind and how detail of information can be recovered by interpolation and what is the limit of the recovery. A series of decimations were designed to test interpolation until it failed.

Method and Results

A typical orthogonal land seismic survey was used for this study. The survey has shot lines with the line spacing of 300 m and shot station interval of 60 m. Receiver lines are with a line spacing of 180 m, and receiver station interval is 60 m. The normal stacking fold for the natural CMP bin size (30 x 30 m^2) is only 8 at 700 m offset, which is low compared to the average survey design. To maintain the stacking fold at a reasonable level, the processing CMP bin size was defined as 60 x 60 m^2, which is four times bigger than the natural CMP bin size in area. The normal fold at 700 m offset is 29. First, the original data (**full data**) was processed to get the best processing sequence and the structural stack was used as a bench mark for further tests. Interpolation was applied to the “full data” to test the algorithm itself to make sure the interpolation preserves geological features and enhances the image. Afterward, a series of decimation tests were conducted to investigate the power of interpolation: case 1. removed every second shot line so the remaining data (**1/2 data**) is only one-half of the “full data”; case 2. removed every second shot and receiver lines so the remaining data (**1/4 data**) is only one-quarter of the “full data”; and case 3. removed every second shot and receiver lines, and every second shot station from the remaining shot lines so the remaining data (**1/8 data**) is only one-eighth of the “full data”. The same processing sequence developed for “full data” was applied to all three decimated datasets (1/2,1/4 and 1/8 data).

The interpolation method used for the tests is the Anti-Leakage Fourier Transform (ALFT) (Xu et al, 2004), which works in 5D frequency-wavenumber domain of time, in-line, cross-line, offset and azimuth. By solving Fourier coefficients of the wavefield from irregularly sampled seismic data, ALFT is able to reconstruct the wavefield, regularize spatial sampling and fill missing traces.

Due to the large velocity contrast just above the zone of interest (ZOI), the reflections around the ZOI suffer severe NMO stretch and the signal-to-noise ratio is low beyond 600 m offset. It will degrade the quality of final stack if the data at far offset (further than 600 m) are included in interpolation/stacking. To avoid the influence of the bad data at far offset, it is decided only to interpolate the data up to 600 m offset. The number of offsets for interpolation is 16 with the interval of 37.5 m. The number of azimuth chosen for the tests is 4, with the interval of 45^o.

Figure 1 shows the time slices of structural stacks of the full data and three decimation tests without interpolation. All four datasets have obvious footprints. The slice of 1/8 data is very noisy. Geological features in the yellow box can be seen in the full data, but not in the decimated datasets. Large structure in the blue box can be seen in the full data, 1/2 data and 1/4 data, but not clear in the 1/8 data. Interpolation was applied to all four datasets and Figure 2 shows the slices of the stack of all four datasets after interpolation. From left to right: full data, 1/2 data, 1/4 data, and 1/8 data. Footprints were eliminated by interpolation; signal-to-noise ratio is higher and images are cleaner for all four datasets compared to their own counterpart in Figure 1. Geological features in the yellow box were enhanced by interpolation for the full data; well recovered by interpolation for 1/2 data; recovered mostly for 1/4 data except some small details; but not able to be recovered for 1/8 data due to the extreme sparseness of the input to interpolation. However, the large structure in the blue box was successfully recovered by interpolation for 1/8 data.

From the tests for this survey, interpolation recovered small geological features as small as 2-3 CMPs, which is close to the original receiver line spacing and 1/2 of the original shot line spacing, from slightly decimated data (1/2 data), but only recovered large scale geological features, >5 CMPs, from heavily decimated data (1/8 data). Roughly speaking, images with interpolation can provide as much detail as that from a twice-denser survey without interpolation. Please note that these numbers are based on this particular 3D survey solely, and may vary in some degrees for other surveys. However, the principle remains that interpolation is able to recover some missing information and the sparser the acquisition geometry is, the larger the size of geological features can be recovered by interpolation.

Besides recovering missing geological features, interpolation can eliminate acquisition footprints, remove random noise and improve the quality of seismic image.

Conclusions

Through this series of decimation tests, interpolation shows its power to improve the quality of the seismic image and recover some of missing data. The benefits of interpolation are: 1. elimination of acquisition footprints; 2. increase of signal-to-noise ratio and sharpness on final images; 3. most importantly, recovery of some geological features. The ability of structure recovery is largely dependent on the severity of the decimation. Interpolation can recover small features from lightly decimated dataset, but is only able to recover large structures from heavily decimated dataset.

Depending on the size of the features of interest, seismic survey might be shot with a coarse geometry, e.g. regional surveys, to reduce the cost of acquisition. During the processing stage, 5D interpolation can be used to recover the structures that cannot be well imaged from conventional processing. From this decimation study, it is suggested that by using 5D interpolation, one can shoot less shots (1/2 – 2/3 total number of shots) compared to conventional acquisition design, and still get similar quality of final image. Crook et al (2013) discussed in details regarding the strategy of field acquisition design in combination of 5D interpolation in processing.

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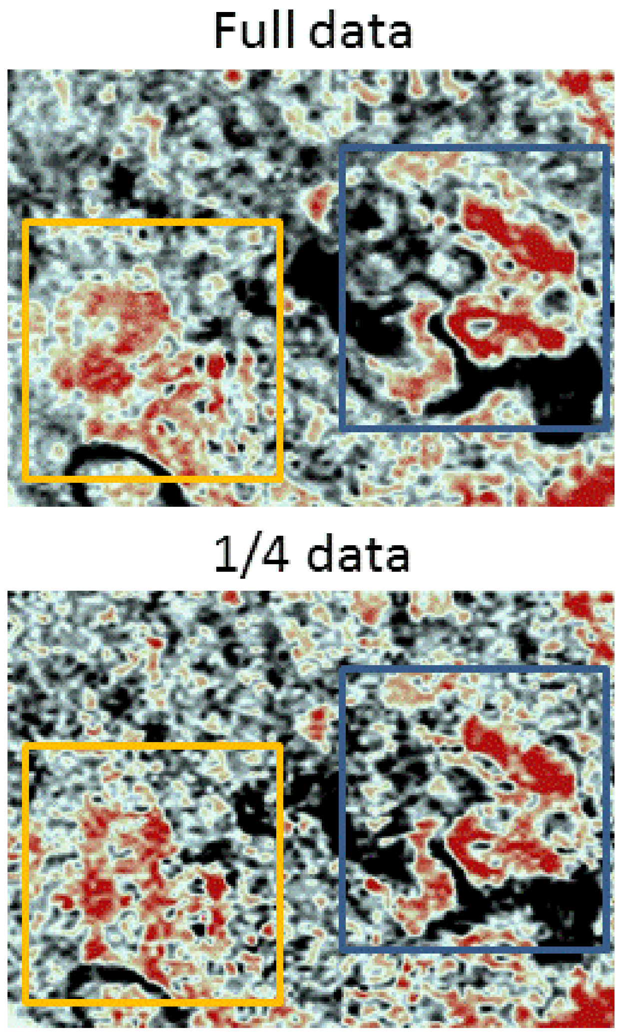

Figure 1: Slices of the stack of all four datasets without interpolation. All four slices have footprints to different degrees. The slice of 1/8 data is very noisy. Geological features in the yellow box can be seen in the full data but not in decimated datasets. Large structure in the blue box can be seen in the full data, 1/2 data and 1/4 data, but not clear in 1/8 data.

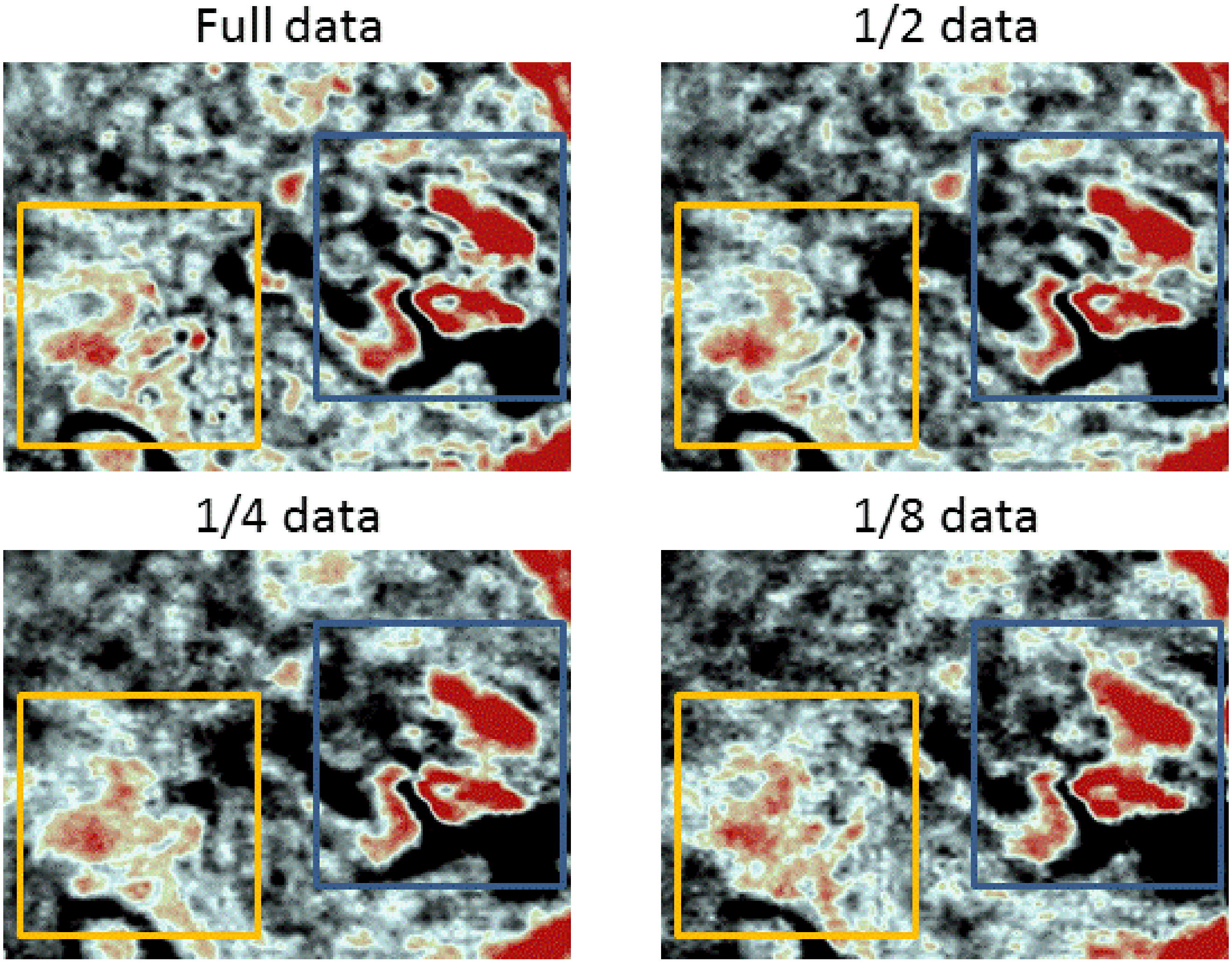

Figure 2: Slices of the stack of all four datasets after interpolation. Footprints were eliminated by interpolation; signal-to-noise ratio is higher and images are cleaner compared to Figure 1. Geological features in the yellow box were enhanced by interpolation for the full data; well recovered by interpolation for 1/2 data; recovered mostly for 1/4 data except some small details; but not able to be recovered for 1/8 data. Large structure in the blue box was successfully recovered by interpolation for 1/8 data.