5D interpolation on the basis of preconditioned least-squares migration

The UNIVERSITY of OKLAHOMA
Mewbourne College of Earth and Energy
ConocoPhillips School of Geology and Geophysics
ConocoPhillips

Shiguang Guo*, Bo Zhang, Kurt J. Marfurt

ConocoPhillips School of Geology & Geophysics, University of Oklahoma

AASPI

Summary

Inadequate sampling has been always the problem for seismic acquisition. Obstacles caused gaps during land seismic acquisition can cause migration artifacts. Narrow azimuth data make it difficult for AVAz analysis and full wave inversion, unbalance offset bin separation can hinder AVO analysis. To address these artifacts come from poor data sampling, 5D interpolation was introduced to apply data before migration. Traditional 5D interpolation tried to interpolate the gaps of source and receiver pair to reach denser bin definition, as to increase signal to noise ratio, suppress footprint, in addition to fill in gap where lacks data converge. Our method tried to use demigration based on preconditioned least-squares migration to interpolate seismic data. In addition, comparing the interpolate traces based on source receiver sense, we will interpolate traces on basis of azimuthal offset bin to realize full converge fold. Finally, we found that our new 5d interpolation can increasingly compensate poor fold converge, which allow us to enhance the data quality and suppress footprint, and further apply AVAz and AVO analysis.

Introduction

Various methods of 5d interpolation have been applied to sparse or missing data. Liu and Sacchi (2004) introduced MWNI (Minimum Weighted Norm Interpolation) method for 5D interpolation, the ALTF (Anti-leakage Fourier Transform) method was introduced by Xu et al. (2005), Abma and Kabir (2006), proposed the POSC (Projection Onto Convex Sets) method, others by Stein et al.,(2010) and Wojslaw et al. (2012). Chopra and Marfurt (2013) applied Minimum weighted norm method by Liu and Sacchi on attributes illumination.

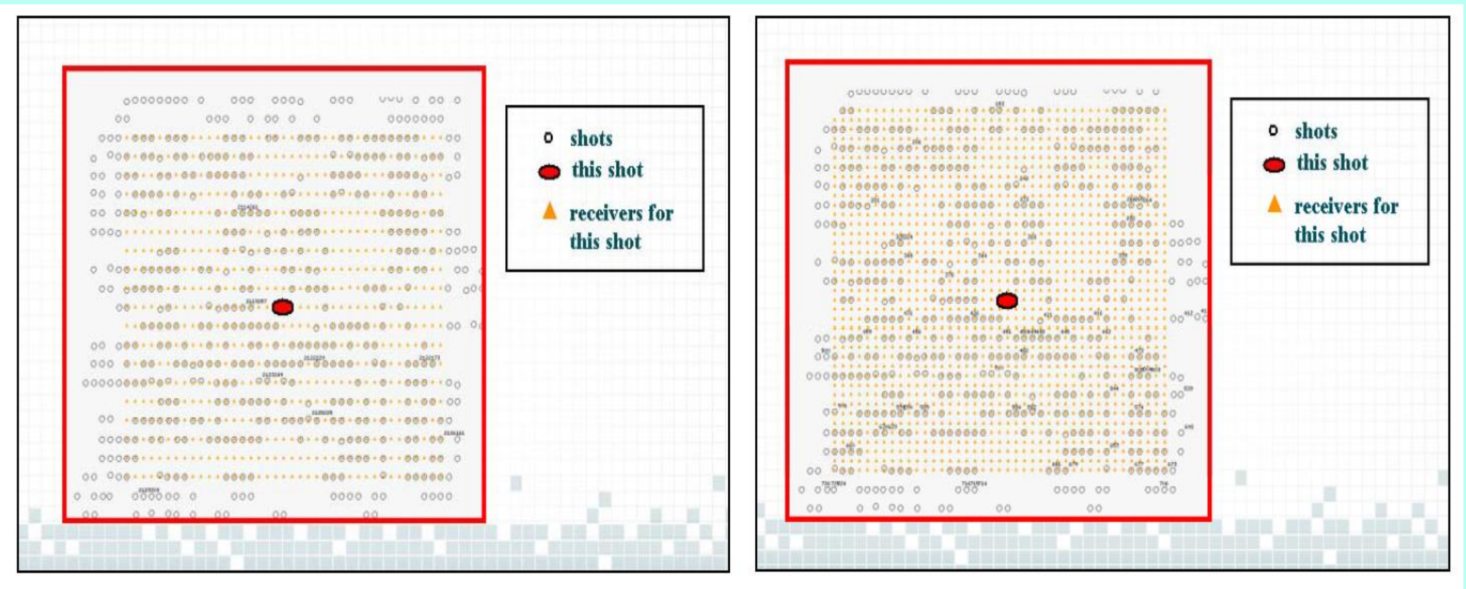

Figure 1. (a) Acquisition before interpolation after (b) interpolation, Trad (2005)

Method

The method we proposed is based on Kirchhoff demigration. We performed prediction for dead traces and lower-fold converge area corresponding to unrecorded offsets and azimuths from gathers. Unbalanced missing traces can cause post–stack and pre-stack artifacts, such as aliasing, footprint and AVO and AVAz requires regularity of azimuth and offset to reach idea performance, in addition, geometric attributes can also get benefits of reconstruction of missing traces.

Migration

$$m(\xi) = \int_{\Omega_\xi} W(\xi, q, h) \frac{\partial}{\partial t} d[t = t_D(\xi, q, h), q, h] dq dh$$

Demigration

$$D(t, q, h) = \int_\sigma W(\xi, q, h) \frac{\partial}{\partial t} m(t_\xi, x_\xi, y_\xi) dx dy$$

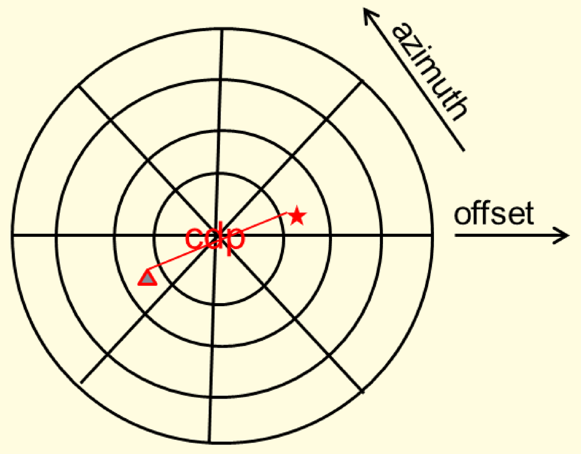

Figure 2. A typical azimuth and offset bin

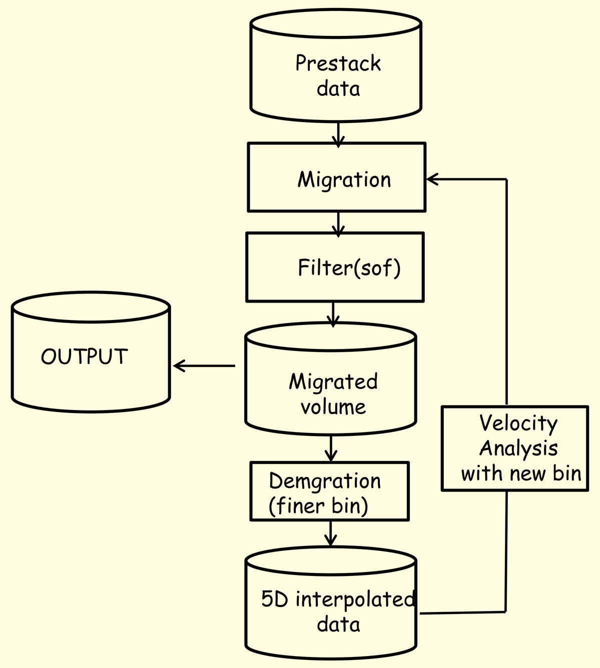

Figure3. Workflow of 5D interpolation

Application

Osage County is home to the Osage Indian Reservation and is located in northeastern Oklahoma, sharing a northern border with the Oklahoma-Kansas state line. The Mississippian chert was formed at the unconformity between the Pennsylvanian and Mississippian in north-central Oklahoma and south-central Kansas. It has low density and high porosity, it is also characterized by karsts features, which make it a good reservoir rock. We applied one azimuth and 50 offsets scan for original bin coverage, and reconstructed the gathers where the fold is zero, note fold map comparison below.

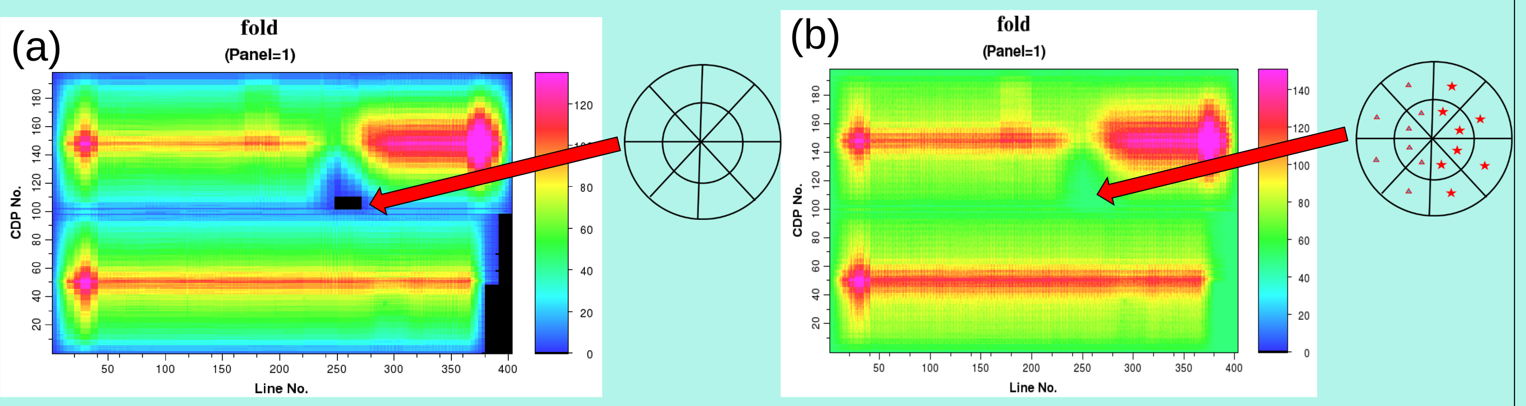

Figure4. (a) Fold map of survey before interpolation (b) after interpolation. The area red arrow denote in figure a is where the fold is zero, and after interpolation, the fold converge improved in same area.

Future work

Try more bin converge with finer cdp and line definition, apply new velocity analysis. In addition, we will introduce preconditioned least-squares migration on 5D interpolation with prestack sof filter. Explore the possibility of wide azimuth interpolation for narrow azimuth dataset, so as to perform AVAz analysis for narrow azimuth acquisition data.

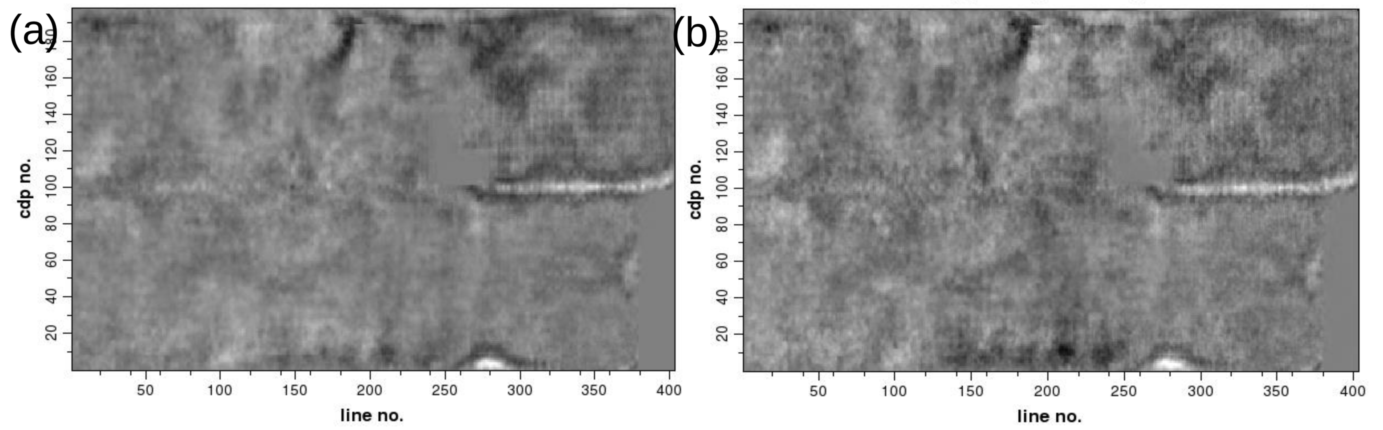

Figure 5. Time slice map at 0.24 seconds through stacked volume (a) before 5D interpolation, (b) After 5d interpolation.

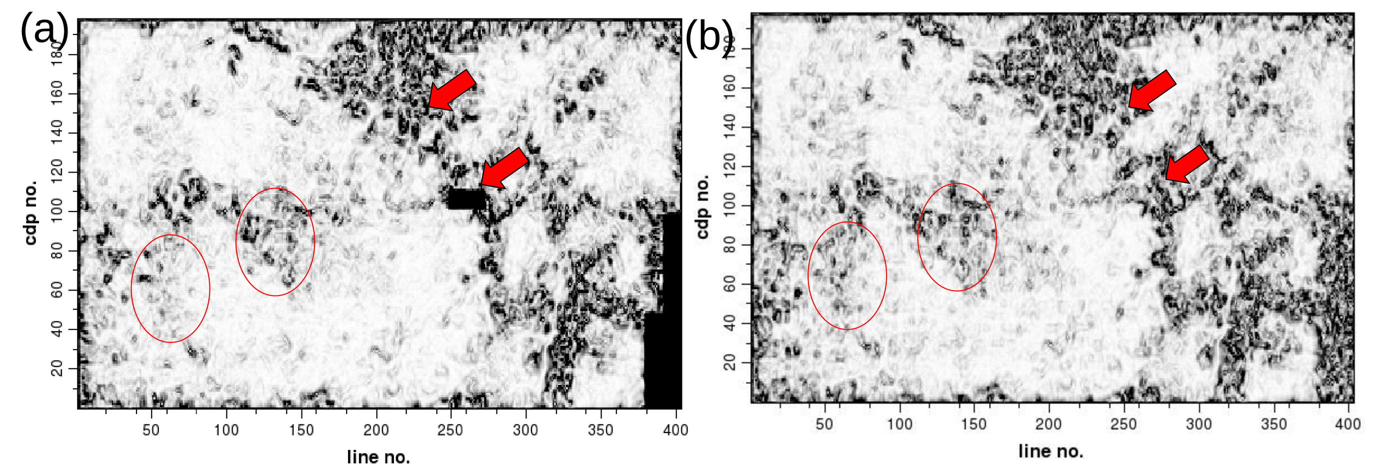

Figure 6. Time slice map at 0.68 seconds through Sobel-filter similarity (a) before 5D interpolation, (b) After 5d interpolation.

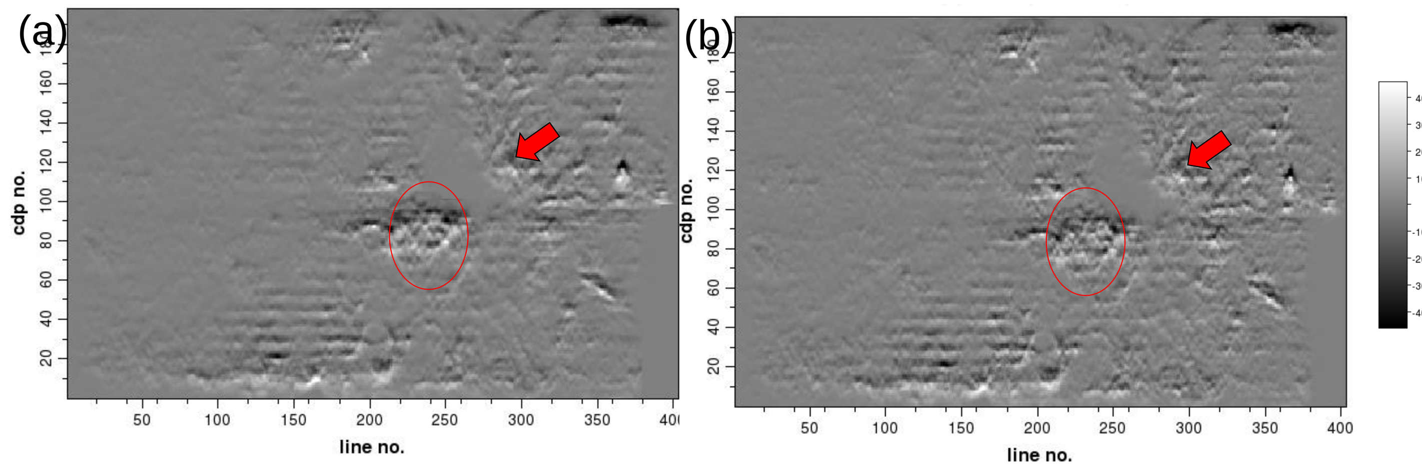

Figure 7. Time slice map at 0.58 seconds through most inline energy gradient (a) before 5D interpolation, (b) After 5d interpolation.

Conclusion

Through the application of 5D interpolation on Osage County, we found 5D interpolation can suppress footprint a little bit from time slice of figure 5. In addition, 5D interpolation can not only reconstructed missing traces from figure 6 as the red arrows denote, but also give rise to high resolution for geometric attribute image such as similarity and curvature illumination as red cycles denote from both figure 6 and figure 7.

Acknowledgement

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