Application of data Regularization Based on Optimized Matching Pursuit method in Qaidam basin

Introduction

Seismic data processing techniques, particularly migration, have strict requirements on the regular spatial distribution of traces, that is, data should be sampled without spatial aliasing and regular within migration aperture, wide-azimuth, uniformly illuminated. However, due to the bad survey geometry condition (Figure 1), seismic datasets do not fulfill these requirements, as a result, the following processing such as migration will suffer from poor processing results. Although not a substitute for well-sampled field data, data reconstruction or interpolation methods performed on pre-stack seismic data can provide a better result.

Figure 1 Topography of survey.

The data regularization methods are mainly divided into two categories: one kind is model-based regularization methods. Formal (1999) proposed an offset mapping based regularization method to map data from one offset to another. The other kind is mainly based on signal analysis. It assumes that the seismic event is linearly predictable, and the main idea is to reconstruct the Fourier spectrum of regular sampling data. Some popular interpolation methods are as below.

- MWNI Minimum Weighted Norm Interpolation (Liu, 2004; Liu and Sacchi, 2004; Trad 2009)
- MPFI Matching Pursuit Fourier Interpolation (Nguyen and Winnett, 2011; Schonewille et al., 2013)

With wide azimuth geometries it is necessary to use an algorithm that respects all recording dimensions simultaneously. We will discuss a method for implementing 5D interpolation through a case study in the northwest of China to show how this technology can improve processing for a range of different datasets and its potential for bringing new life to legacy data.

Theory

MPFI is a frequency domain method derived from ALFT. The data are transformed from the space-time domain to the frequency-wavenumber domain by discrete Fourier transform. The following steps are done for each frequency slice. We estimate Fourier coefficients recursively, beginning with the one with the maximum energy and proceeding down to the minimum energy. After each coefficient is estimated, an inverse irregular Fourier transform is used to remove it from the input data, thus significantly reducing spectral leakage. Furthermore, the final updated input data on the irregular grid will tend to zero after all the subtraction operations. This implies the reconstructed data from obtained Fourier coefficients will fit the original measurements and satisfied the demand of interpolation of seismic data.
The improvement of the method is to select the component of maximum energy from the lower frequencies, with this priors, it is much more likely that the true events instead of the aliases are chosen. This is represented in Figure 2 with a field data example after 20% random extraction of Marmousi model data (Figure 2a). In Figure 2b, we can see that the true event appear in the lower frequencies, while there are the alias energy in the higher frequencies. That is why we apply the priors to the lower frequencies. The reconstructed data and f-k spectrum is shown in Figure 2c and Figure 2d. It is proved that the optimized MPFI can interpolate complete data without aliasing.

![Figure 2 Illustration of sparseness in the Fourier domain: a) Input data; b) f-k spectrum of input data; c) Interpolated data using MPFI; d) f-k spectrum derived priors from lower frequencies.](image)

**Field data example**

The full coverage area in the survey is 500km\(^2\). As it can be seen from Figure 3a, the shot line is extremely irregular, leading to blurred fault imaging in the target area and affecting structural delineation and subsequent interpretation. By the improved MPFI regularization method, the acquisition system is redefined, the shot line is become regularized (Figure 3b), and space sampling is more even. It is noteworthy that as the data use the real coordinate of acquisition system, the data after regularization can be sorted to the shot domain, migration processing can be not only done in the offset domain but also in the shot domain, which provides a more flexible preparation for subsequent migration.

![Figure 3 Shot (green) and receiver(blue) geometry for the original survey(a), and after 5D data regularization (b)](image)

The poor S/N ratio on the raw gather and stack (Figure 4a and 5a) is due to the low fold of data combined with a variable offset/azimuth sampling that gives rise to an inconsistent stack response. Stack timeslice comparisons for the tests are shown in Figure 6. As the different fold in different survey and highly variable offset/azimuth distribution, the input stack section is noisy and the events show poor continuity (Figure 6a). After data regularization, we can see a great improvement in the signal to noise ratio as well as the fold due to a consistency in sampling. Figure 7 shows a comparison of pre-stack time migration section between before and after regularization in the inline direction, and
highlights the improvement in the continuity of events as well as reconstruction of the shallow section in the box, finally we have a clearer image with higher S/N ratio.

Figure 4 CMP gather before(a) and after(b) 5D regularization

Figure 5 stack section before(a) and after(b) 5D regularization

Figure 6 Timeslice before(a) and after(b) 5D regularization
Conclusions

We have applied the optimized MPFI technology to a 3D land survey in the northwest of China, aimed at dealing with the gaps in the geometry and the severe low S/N ratio, the results show that our method is able to fill the gaps in the data while preserving AVO, AVAz and the details of the seismic wavefield. Because a 5D operator is used, it makes the best use of the available dimension, whether it is azimuth, offset or x and y coordinates in the CMP domain. Furthermore, it will also improves the imaging results through effective pre-conditioning for seismic data processing which often assumes that our data are regularly sampled while it is sparse and irregular in truth.

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References