Missing Trace Restoration by Interpolation on 3D Regular Seismic Grid

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Summary

3D trace interpolation to restore the missing traces which were either not recorded due to acquisition constraints or heavy editing of noisy, spiky, sluggish and mono-frequency traces while processing the data is of prime importance in 3D Pre-stack processing. Due to the presence of an obstacle all offsets cannot be recorded, there is a progressive fold deficiency and a progressive shortage of small to large offsets. The irregular fold distribution in the input gathers, generally translates into a variable resolution and signal-to-noise ratio. These variations lead to detrimental acquisition imprints on the stack sections. The fold variation also affects the velocity analysis and continuity of events on the stack sections. Further this fold deficiency impacts the phase and amplitude stability of the imaged reflectors thus impacting the signal character. Starting from poorly populated CMP gathers the procedure is to restore the missing offsets in a 3D sense using F, K_x, K_y interpolation.

After restoration, due to the uniform foldage now available in the CMP gathers these imprints are expected to fade away. The fold variograms are studied as QC measures and the signal-to-noise ratio on the prestack gathers are plotted.

The magnum bonum of trace restoration helps velocity analysis, removing acquisition imprints and increase of resolution on the stack sections. The technique is applied on a 3D artificial dataset as well as on a real 3D seismic dataset from Krishna-Godavari basin, India and the results are found to be very encouraging.

Introduction

The amount of surface effort employed during 3D acquisition has a direct bearing on both the final image and the acquisition cost. For marine acquisition the use of dual sources has been found to be an efficient trade off between the acquired fold and the number of subsurface lines that can be recorded within each sail-line. In practice the acquired fold is often too low for multiple attenuation and interpolation is used to increase the fold of the data by generating the ‘missing’ shots that would have been recorded had a single source been used (Jakubowicz, 1994). For modern, high quality marine data this provides an effective solution. For 3D land and transition zone acquisition the situation becomes more complicated. Decimation tests have shown in the past that reasonable data quality may be maintained even after quite high levels of data reduction (Bouska, 1996). However, for land 3D surveys the data must be sufficient to resolve any statics problems, attenuate noise and multiples and to give reliable velocities. As in the marine case it is desirable to try to interpolate ‘missing’ data in order to improve any or all of these processing steps.

Compared to the marine case, the interpolation of land data is not straightforward. Marine data will typically be relatively regularly sampled and noise free, making it ideal for efficient and accurate interpolation. In contrast, land data may be irregularly sampled and frequently contaminated by high amplitude and severely aliased noise. The important questions regarding the acquisition of land data become:

1. What are the spatial sampling requirements for imaging?
2. What are the spatial sampling requirements for noise attenuation?
3. What is the effect of sparse sampling on statics and velocities?

The use of interpolation is linked to these issues. For example, should noise be attenuated before attempting any interpolation or is it possible to interpolate severely aliased, high amplitude noise events? Because of the variety of 3D geometries and variations in survey conditions (i.e., noise, multiple, statics etc.) it is necessary to consider these effects on a range of different surveys.

3D prestack processing is gaining importance to satisfy the conditions so as to facilitate prestack time and depth migration and also Amplitude variation with offset (AVO) studies. A properly planned 3D seismic survey is always a boon to a processor to have uniform population of traces in each bin and the processing can go san souci. But it is always not possible to meet the theoretical conditions
due to surface obstacles and demographic restrictions in the field that force to acquire non-uniform bin coverage. The bin coverage some times can be regularly irregular or irregularly regular which cause progressive fold deficiency and a progressive shortage of small to large offsets. The irregular fold distribution in the input gathers, generally translates into a variable resolution and signal-to-noise ratio. These variations lead to detrimental acquisition imprints on the stack sections. The fold variation also affects the velocity analysis and continuity of events on the stack sections. Further this fold deficiency impacts the phase and amplitude stability of the imaged reflectors thus impacting the signal character. Therefore there is an inevitability to restore the missing traces by way of interpolation in a 3D sense using any appropriate algorithm and domain to assist amplitude adaptation. A variety of different interpolation algorithms were tested, including two-pass $\tau$-p, one-pass $\tau$-p-q, two-pass FX and one-pass FXY. The best results were found to come from the FXY algorithm. Alternative algorithms for such interpolation might include model based shot continuation methods (Mazzucchelli et al, 1998). In the present paper, it is proposed to use an $F, K_x, K_y$ interpolation methodology to restore the missing traces on a 3D regular grid. As a testament, the technique is applied on a 3D synthetic stack data to restore the missing traces, which have been consciously removed from the 3D data grid. Later the same is applied on a real 3D dataset from Krishna-Godavari basin which has irregular fold variations due to acquisition constraints as well as heavy editing of spiky, sluggish, noisy and mono-frequency traces and the results are presented.