USING SIMILARITY ATTRIBUTE AS A QUALITY CONTROL TOOL IN 5D INTERPOLATION

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Summary

Seismic attributes in the last two decades have been used in the industry to primarily map structural and stratigraphic structures such as faults/fractures, anticlines, synclines, unconformities, pinchouts, channels and other traps in quantitative interpretation. Their practical use however in routine seismic data processing quality control (qc), such as to test and compare different workflows as well as optimizing processing parameters has been somewhat minimal.

In this paper, with the aid of a 3D dataset from South Texas and using the similarity or volume coherence attribute, the immense benefit of conventional 5D anti-leakage Fourier transform (ALFT) interpolation over the non-interpolated data and the additional benefit derived from our proprietary 2D input data sampling prior to running the 5D ALFT interpolation in prestack time migration (PSTM) is demonstrated. This paper also shows that the similarity attribute when used as a qc tool, can reveal subtle artifacts generated in 5D interpolation processing.

Introduction

Similarity is a measure of the coherence of seismic waveforms and it gives a quantitative measurement of the changes in reflection that depicts different stratigraphic/structural features or traps that are of interest in hydrocarbon exploration. A high level of similarity or coherence indicates a laterally continuous geology such as channels whereas low levels of similarity means broken or discontinuous structures such as faults, fractures and salt diapirs.

Seismic attributes such as similarity offer the interpreter a quick and dirty interpretation of any seismic volume as they reveal interesting geological trends that could be of exploration significance.

In the literature, the similarity attribute was first introduced by Bahorich and Farmer (1995) and their method was based on normalized cross-correlation. Later, Marfurt et al. (1998) introduced coherency attributes based on semblance. Bednar (1998) and Karimi and Fomel (2013) have proposed the prediction error filter coherency algorithm. Gersztenskorn and Marfurt (1999) and Chopra and Marfurt (2017) developed and utilized coherency algorithms based on eigenstructure. Alaudah and Alregib (2016, 2017) introduced the Generalized Tensor based coherence (GTC) and directional GTC attributes.

Liu et al. (2017) recently developed the enhanced coherency attribute based on principal component analysis (PCA). This technique reduces redundancy within the vertical analysis window where there is already high coherency whereby emphasizing more of the subtle lateral changes. Qi et al. (2017) introduced the concept of multi-azimuth coherence where the covariance matrix is modified to be the sum of all the covariant matrices of the azimuthally limited volumes. This has the advantage of preserving subtle discontinuities, avoiding smearing of lateral variations and suppressing incoherent noise.

Most of the advances in seismic attribute analysis and research has been to aid the interpretation of seismic data for exploration and drilling purposes. There has been very little application of attributes to qc seismic data processing. Marfurt and Chopra (2006) have discussed the use of seismic attributes to qc statics and velocities in routine seismic data processing. De Abreu et al. (2017) have used spectral decomposition and coherency as tools to compare and contrast two 3D datasets independently acquired and processed.

This paper shows the application and advantage of the similarity/coherence attribute over the regular amplitude time slice to quality control and compare three datasets namely: non-interpolated, conventional 5D ALFT interpolated and 5D ALFT interpolated with prior 2D interpolation before prestack time migration (PSTM).

Theory and/or Method

Tingdahl and De Groot (2003) have described the theoretical basis of the similarity algorithm used for the analysis in this work. The samples of the trace segments are considered to be vectors in hyperspace. Similarity is then defined as the Euclidean distance between the vectors normalized over the vector lengths. Similarity of one and zero indicate that the trace segments are indentical and non-identical respectively. In this paper, a non dip-steered similarity calculation with a time window of 28 ms (+ and – 14 ms) was used.

Kola-Ojo (2017) has given the theoretical basis of the two 5D interpolation techniques used for the tests in this research. The first is using the conventional 5D ALFT regularization while the second method employs a prior 2D interpolation before running 5D ALFT interpolation.

Example

The 3D data example used for the tests was acquired in South Texas in USA. The east-west receiver lines are spaced 1320 feet apart and the north-south shot lines are spaced 880 feet apart. Distance between receivers was 110 feet while the distance between shots was 220 feet. The natural bin size therefore is 55 by 110 feet. Inlines are east-west and crosslines are north-south.

The first test was conducted by prestack migrating into a 55 by 55 foot bin without any prior prestack interpolation. The second test involves binning to 55 by 55 feet, running the 5D ALFT interpolation and then prestack migration. The third test involves binning to 55 by 55 feet as the second test, run a prior 2D interpolation as described in an earlier publication (Kola-Ojo, 2017) to pre-populate the bins so as to minimize aliasing, run the 5D ALFT interpolation, prestack migrate and compare the results of the three tests.

In running 5D interpolation, it is expedient and also a good practice to do a leakage test to ensure that there is very little leakage of energy as a result of the 5D parameterization. Figure 1 shows there is a very small leakage in the 5D ALFT interpolation which is within reasonability.

Figure 2 shows example inline sections of the three tests performed on the data. Far left is the first test which is PSTM without interpolation. Middle section is 5D PSTM and the far right section is 5D PSTM with prior 2D interpolation. We see the obvious improvement of the 5D migrated sections over the non-interpolated section. The 5D interpolated sections show better continuity in the shallow and a better migrated structure and sharper faults in the deep as indicated by the circles. The blue horizon on the sections was picked to create the time structure maps for all three volumes. The green horizon which is +200ms shift of the blue horizon was used for the similarity attribute analysis as it cuts across the faults.

Figure 3 shows the time structure (isochron) map of the blue horizon for the three test volumes. The broad north-south anticlinal structure in the middle of the area is consistent for all volumes which shows the 5D interpolation did not compromise the structural event.

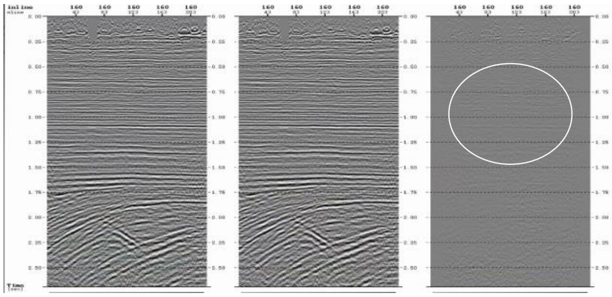

Figure 1: 5D ALFT leakage stack test displayed in grey scale to clearly see the leakage. Far left: input data. Middle: 5D interpolation. Far right: leakage. Leakage is very minimal and mainly limited to the shallow section as indicated.

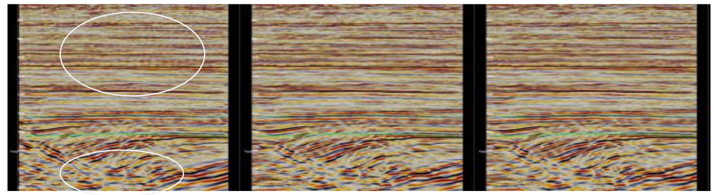

Figure 2: Example inline section. Far left: PSTM. Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation. Note the superior shallow continuity and fault imaging in the 5D sections as indicated by the circles.

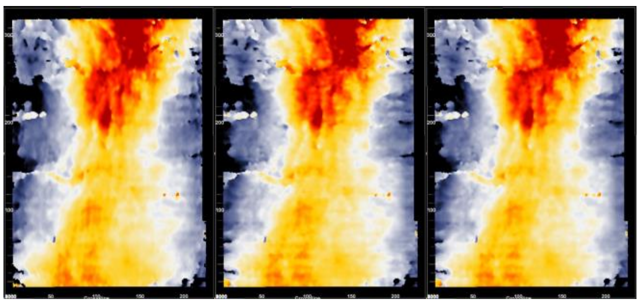

Figure 3: Time structure map. Far left: PSTM. Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation.

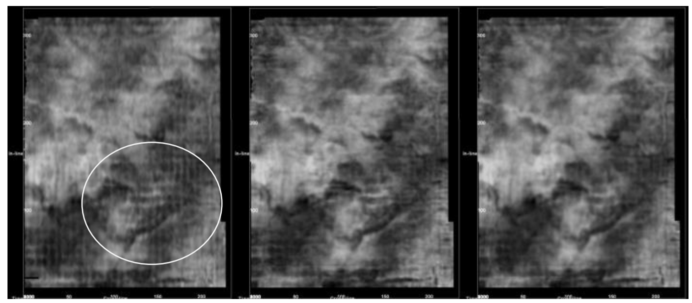

Figure 4: Amplitude time slice 850ms. Far left: PSTM. Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation. Note the clearer image Of 5D PSTM over PSTM. Note also the clearer image of 5D PSTM with prior 2D interpolation over 5D PSTM as indicated by the circle.

Figure 4 compares the amplitude time slices of the volumes at 850ms. We see the obvious improvement of the 5D PSTM over the non-interpolated PSTM. We also see the clearer image of the 5D PSTM with prior 2D interpolation over the conventional 5D PSTM. Figure 5 shows the similarity attribute of the volumes at 850ms. Compared to the amplitude time slice in Figure 4, we see more structure and differences in the volumes using the similarity attribute which aids our qc and comparison. The meandering channel structure (arrows in Figure 5) is better imaged in 5D PSTM than in PSTM. On the other hand, the 5D PSTM with prior 2D interpolation shows clearer and crisper structure than conventional 5D PSTM as it better handles the aliasing and other noise contaminations. The similarity attribute gives us more latitude for qc and comparison than ordinary amplitude time slices or vertical time sections.

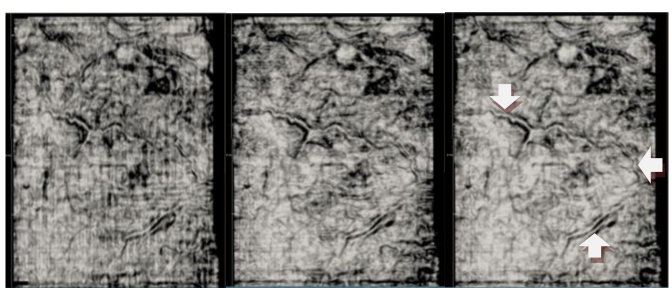

Figure 5: Similarity time slice 850ms. Far left: PSTM. Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation. Note the better imaged meandering channel in 5D PSTM compared to PSTM. Note also the even clearer image of the far right over the image in the middle. The 5D PSTM with prior 2D interpolation better handles the aliasing and other noise contaminations. Also, the similarity attribute gives us more latitude for qc and comparison compared to the amplitude time slices in Figure 4. Arrows indicate the meandering channel.

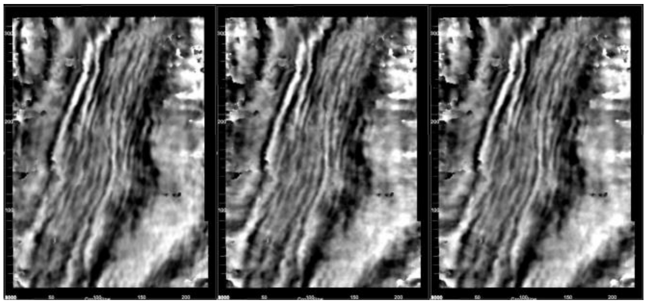

Figure 6: Amplitude time slice along green horizon. Far left: PSTM. Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation.

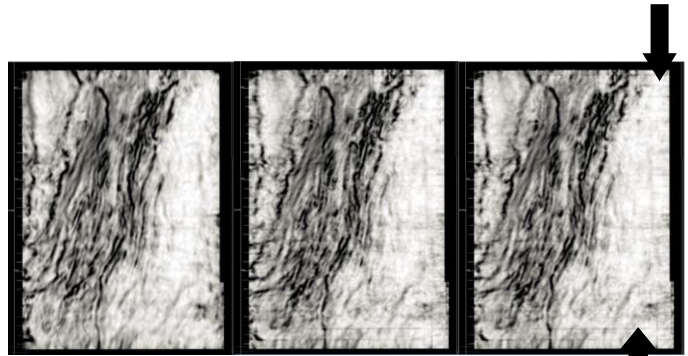

Figure 7: Similarity time slice along green horizon. Far left: PSTM Middle: 5D PSTM. Far right: 5D PSTM with prior 2D interpolation. Note the east-west artifacts (indicated by the arrows) on both 5D volumes not seen on the PSTM volume. These artifacts are also not visible on the amplitude time slices of Figure 6.

Figure 6 shows the amplitude time slices of the volumes along the green horizon of Figure 2. Figure 7 is the similarity time slices along the same horizon. The similarity time slices show clearer images for comparison and qc purposes. Although the fault imaging (Figure 7) is better in the 5D volumes compared to the PSTM volume, we see some east-west artifacts (indicated by dark arrows) that are not visible in the PSTM slice and are also not seen on the amplitude time slices of Figure 6.

This means that the similarity attribute has the ability to bring out hidden and subtle processing artifacts that may be difficult to see on vertical time sections and horizontal amplitude time slices regularly used for qc purposes in seismic data processing.

These artifacts in the 5D interpolation are due to very large offset gaps in the input data due to acquisition constraints. These artifacts are not seen in the 5D volumes in the similarity time slices at the shallow 850ms (Figure 5) because of the dominance of the acquisition footprint. The 5D leakage test of Figure 1 shows that the 5D parameterization was very reasonable.

Conclusions

With the aid of this dataset and using the similarity attribute as a quality control tool, this paper shows that the conventional prestack 5D ALFT interpolation datasets are better than the non-interpolated dataset. We also see the improved benefit of a prior 2D interpolation before running the 5D ALFT interpolation in minimizing aliasing and other noise contaminations.

Finally, apart from the clearer subsurface picture the similarity attribute presents in processing qc, we see the additional benefit of it revealing subtle artifacts that may otherwise be missed when using only vertical sections or horizontal amplitude time slices for qc purposes.

Acknowledgements

The author would like to thank the Bureau of Economic Geology at the University of Texas at Austin for providing the raw data for this work.

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