Gleaning Meaningful Information from Seismic Attributes

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Summary /Introduction

Seismic attributes form an integral part of most interpretation projects completed today. For doing an effective job or for extracting accurate information from seismic attributes, the input seismic data needs to be optimally processed. The term 'optimally' essentially means that any or all distortion effects, whether near-surface, or amplitude/phase related, or others are taken care of during processing if not totally eliminated. When such pre-stack or poststack data are loaded on workstations, they may still show a certain amount of noise level. This noise could be of various sorts - acquisition related, processing artifacts or random. In this presentation we focus our attention on conditioning of such data for derivation of attributes from them. Besides this, we also discuss the use of some of the procedural steps for noise filtering and dip-steering options for computation of some geometric attributes like coherence and curvature. Finally in this context, we also discuss the impact the choice of algorithm can have on the final results. All these factors ensure that the seismic attributes yield more accurate information for interpretation.

Data Conditioning

Amongst others, a mean filter, an alpha-trimmed mean filter or a median filter are commonly used during processing to tackle random noise. A more desirable application would be of a dip-steered mean or median filter, which has the effect of enhancing laterally continuous events by reducing randomly distributed noise and at the same time not wiping out structural reflection detail. The filter picks up samples within the chosen aperture along the local dip and azimuth and replaces the amplitude of the central sample position with the median value of the amplitudes. The median filter can also be applied iteratively, which will reduce random noise at each successive iteration, but will not significantly increase the high frequency geologic component of the surface. Figure 1 shows a segment of a seismic section before (Figure 1a) and after (Figure 1b) application of a 3-point median filter. Notice the cleaner background and the focused amplitudes of the seismic reflections after median filtering. Attributes run on median-filtered data exhibit cleaner-looking features as well as background. Figure 1c and d shows strat-slices from the coherence volumes generated before and after median filtering. The noise in the background is toned down and the features are seen as somewhat more coherent after median filtering. The patchy low coherence features correspond to Devonian reefs that grew in phases, as indicated by almost vertical gaps between these features.

Structure-oriented filtering

As dip-steered mean or median filters and alpha-trimmed mean filters work on seismic data, they smear fault information, besides marginally lowering the frequency content of the data.

Hoecker and Fehmers (2002) address this problem through the use of an 'anisotropic diffusion' smoothing algorithm. The diffusion part of the name implies that the filter is applied iteratively, much as an interpreter would apply iterative smoothing to a time-structure map. Most important, no smoothing takes place if a discontinuity is detected, thereby preserving the appearance of major faults and stratigraphic edges. Luo et al. (2002) proposed a competing method that uses a multiwindow (Kuwahara) filter to address the same problem. Both approaches use a mean or median filter applied to data values that fall within a spatial analysis window with a thickness of one sample.

Marfurt (2006) describes a multiwindow (Kuwahara) principal component filter that uses a small volume of data samples to compute the waveform that best represents the seismic data in the spatial analysis window. Seismic processors may be more familiar with the principal component filter as equivalent to the Kohonen-Loeve (or simply KL) filter. Figure 2 shows a comparison of time-slices before and after pc filtering on a seismic data set from Alberta. Notice not only the overall cleaner look of the section after pc filtering, but also the sharpening of the vertical faults. The filter was applied iteratively twice such that the end result depends on 49 neighboring traces. Figure 2 uses 99 overlapping windows each of which consists of nine-traces, and 11 samples (± 10 ms) parallel to the dip/azimuth at the center of each window. We then apply our principal component (pc) filter to the analysis point using the window that contains the most coherent data. Because it uses (for our example 11 times) more data, the pc filter in general produces significantly better results than the corresponding mean and median filters. Notice the sharpened faults as well as the overall reduced background noise level.

Figure 3 shows a comparison of time slices from the input seismic data (Figure 3a), the seismic data filter with a 3-point dip-steered median filter (Figure 3b) and the seismic data filtered with PC-filtering (Figure 3c). Notice, as shown in the highlighted ellipses, the PC-filtered display follows the features more closely on the time slices rather than the median filtered display. Similarly, the yellow arrows on the PC-filtered display shows up a pattern in red similar to the input but the median filtered output shows a weakening of amplitudes on those features. Improved event focusing and reduced background noise levels after structure-oriented filtering are clearly evident.

Dip-Steering Option During Computation of Geometric Attributes

Usually estimation of coherence is done under the assumption of flat events or zero dip, or in other words by disregarding dip. For data with dipping reflection events, this could particularly lead to misleading results. Because semblance variance or eigen-decomposition algorithms typically include many traces about the desired output location, the local reflector dip and azimuth should be completed as a first step. Both semblance and variance estimates of coherence of seismic data are currently provided as options on the interpretive workstations. In the interest of computational efficiency, dip-steering options are either not provided or are not robust enough to handle the computational accuracy. A good workflow would involve a direct search of volumetric dip and azimuth prior to or as part of the coherence calculations. This could be 50-200 times more intensive computationally than a coherence calculation with a dip-steering option. Such computations are usually implemented on clusters in a processing center. In such a scenario, the interpreter loads a precomputed coherence volume that includes the advantage of an explicit volumetric dip and azimuth search and then extracts either time slices or horizon slices.

Figure 4 shows time slices from two different coherence volumes. To the left, is a time slice from a coherence volume generated without the dip-steering option. Note the artefacts (sometimes also called structural leakage) following structural contours on our coherence image that complicates interpretation. On the right we show the same time slice where we correctly calculated coherence along a non-zero estimate of dip/azimuth. We now see the faults clearly, uncontaminated by structural artefacts.

Choice of Algorithms

Different algorithms are based on different methods which in turn have specific assumptions and consequently have different limitations. For coherence computation for example, algorithms based on cross-correlation (Bahorich and Farmer (1995)), Semblance (Marfurt et al (1998) and eigen-decomposition of covariant matrices (1999) are available. Another algorithm (which we refer to as EnerComp^{SM}) which we refer to as the fractional derivative has also been reported (Reference). Another algorithm based on the eigen-decomposition of covariant matrices utilizes the use of energy eigenvalues instead of the ratio of eigenvalue ratios. We show examples in Figures 5 to illustrate the usefulness of the choice of the algorithm in conjunction with structure-oriented filtering. In Figure 5 we show a comparison of a semblance horizon slice from north-east British Columbia, Canada, with equivalent slice from dip-steered EnerComp^{SM} coherence volume run on PC-filtered data. Notice the clear definition of not only the main channel running almost north-south but the branching channels also show up clearly, especially the ones to the left.

Conclusions

We have analyzed three important considerations for computation of geometric attributes taking the coherence attribute as an example. These three considerations are 1. data conditioning 2. using dip-steering option for data with reflector dips and 3. the choice of algorithm. We show that structure-oriented filtering run on seismic data sharpens the subsurface features of interest and tones down the background noise. Coherence attribute generated on such seismic volumes yields crisper features. Dip-steering option when used in coherence computation results in clearer looking volumes that are devoid of any structural contour patterns and so prevent misleading interpretation. Finally, a coherence algorithm based on the method of eigen-decomposition of covariant matrices called EnerComp^{SM} demonstrates the superior performance than other available algorithms. These three considerations when adhered to in conjunction yield superior displays for interpretation and should be embraced by seismic interpreters.

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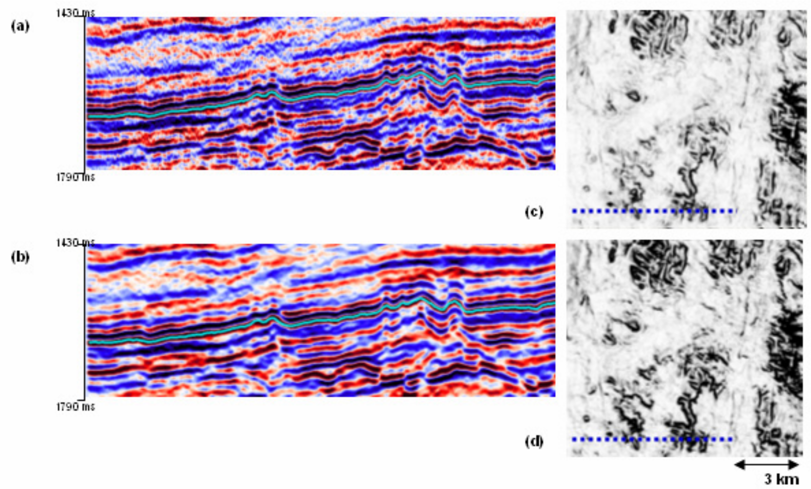

Figure 1: Segment of a seismic section (a) before and(b) after application of a five-by-five median filter. Notice the cleaner background and focused amplitudes of the seismic reflections after median filtering. Strat slices through coherence volumes run on (c) the input seismic volume, and (d) the median filtered seismic volume, 76 ms below the horizon shown in (a) and (b). Notice the cleaner looking low coherence features (*Data courtesy of Arcis Corporation, Calgary*)

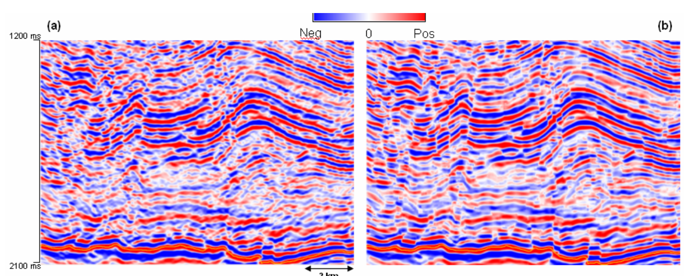

Figure 2: Seismic data (a) before and (b) after structure-oriented filtering. Notice how the fault edges are preserved and the overall background noise has been toned down. (*Data courtesy of Olympic Seismic, Calgary)*

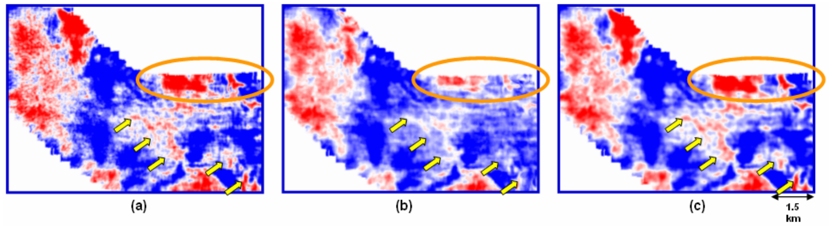

Figure 3: Time slices at 1778 ms through (a) a seismic data volume, (b) the seismic volume in (a) subjected to a five-by-five dip-steered median filter, and (c) the seismic volume in (a) subjected to PC-filtering. Notice the fidelity displayed by PC-filtering as compared with median filtering. *(Data courtesy of Arcis Corporation, Calgary*)

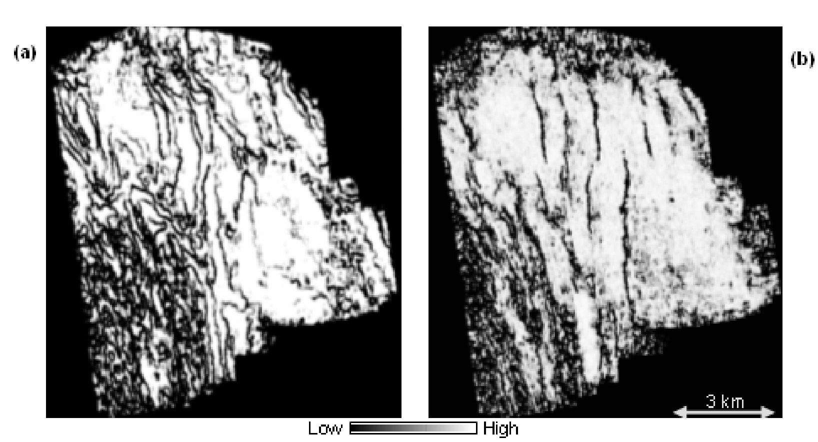

Figure 4: Time slice from (a) coherence volume generated from an input seismic volume without using the dip-steering during coherence computation, and (b) coherence volume generated using a robust dip-steering option during coherence computation. Notice the clarity with which the faults appear on this display. (*Data courtesy of Olympic Seismic, Calgary)*

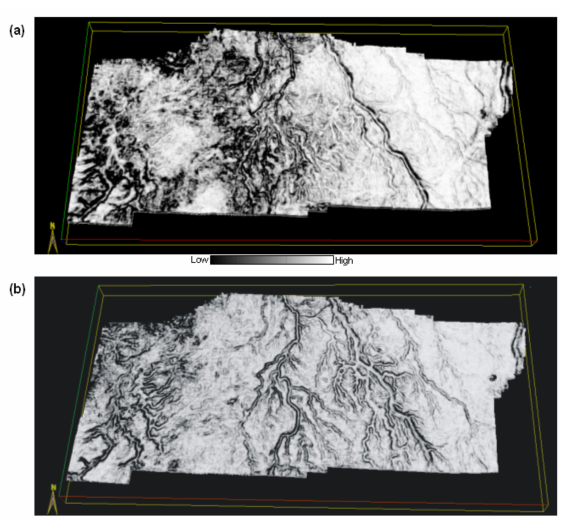

Figure 5: Horizon slice through (a) coherence volume generated using a semblance algorithm directly on input data, and (b) coherence volume generated using EnerComp^{SM} algorithm run on PC-filtered seismic data. Notice the crisp definition of not only the main channel seen in (b) but also the many thin channels on both sides of the main channel. *(Data courtesy of Arcis Corporation, Calgary)*