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A cure for noisy data

Noise reduction techniques provide cleaner datasets.

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A critical factor in virtually every exploration and development project in today's world is the availability of high quality seismic data to help in building the earth model necessary to find and extract hydrocarbons. Acquisition and processing technologies have come a long way in providing the earth scientist with clean, accurate data, but the presence of random and coherent energy-called noise-in the data still limits the precision of such data. We present a method of reducing both of these kinds of noise on seismic data to provide data sets that are cleaner and easier to interpret as well as providing better input to subsequent processing. Use of principal component analysis (PCA) noise reduction along with structurally orient filtering achieves these results.

Seismic data may be contaminated with two types of noise: random noise which is generated by continuous micro-scale vibration and shaking within the earth and coherent noise which is generated by a controlled source not related to direct source to horizon to receiver energy initiated during seismic acquisition. The first type of noise tends to be more apparent on land data and the second type on marine data, although both types may be present in both environments. Many acquisition and processing techniques are available for suppressing such noises including CDP stacking, bandpass filtering, and predictive deconvolution in the pre-stack domain, and dip or velocity filtering, trace mixing, and fx or fxy deconvolution in the post-stack domain. Our technique is a very powerful post-stack dip filter type technique based on principal component analysis that eliminates some of the inherent problems with such types of multi-trace processes.

Theory and Example

Principal component analysis is a well-established mathematical technique for finding commonality among diverse elements. In this case, the diverse elements are a seismic trace and its eight nearest neighbors and the commonality is the local dip and azimuth of the geologic surface passing through those nine points. For each sample in a 3-D seismic survey, we use a small vertical window approximately equal to one period of the data and scan over a range of dips to determine the local geologic surface. This sub-volume is decomposed into individual elements which are analyzed in nine dimensional space using matrix algebra to determine the optimum surface. Random noise is suppressed because it does not relate to any surface and coherent noise is suppressed as long as its dip rate is outside the limits of scanning.

Figure 1 shows a part of a line from a recent three-dimensional seismic survey in Central Texas which shows a substantial amount of noise. Figure 2 shows the result of principal component analysis (PCA) conditioning and the improvement is remarkable. The amount

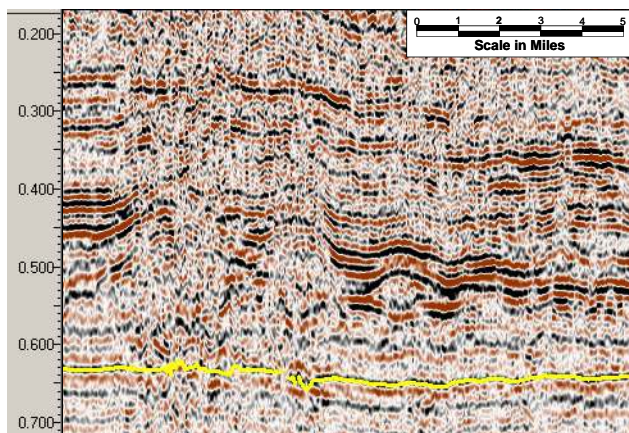


Figure 1: A line from a 3-D seismic survey in Central Texas shows a substantial amount of noise (images courtesy of Geo-Texture).

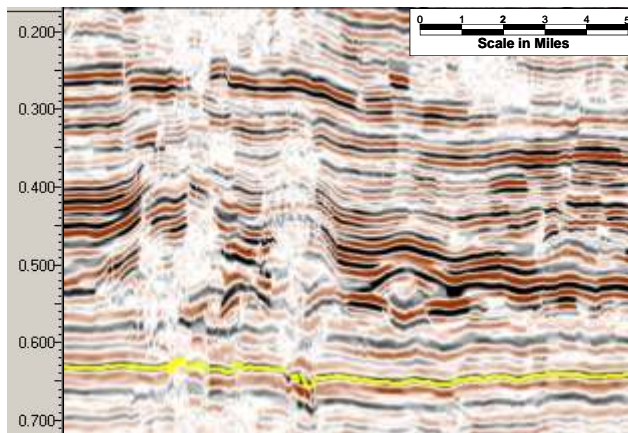


Figure 2: The results of PCA data conditioning.

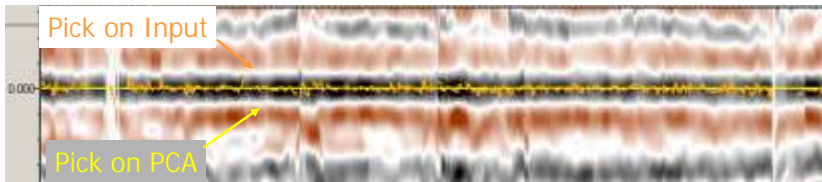


Figure 3: This figure shows a section of the conditioned line flattened on a horizon with auto-picked horizons from the input and conditioned data.

of random noise is substantially reduced and the weak and discontinuous reflections have been shown to be quite continuous in structure and in amplitude. Faults and other breaks in the data have been greatly sharpened. Inspection of the two figures suggests that horizons picked on the PCA data may be smoother than those picked on the Input data and Figure 3 confirms this. Figure 3 shows a section of the conditioned line

flattened on a horizon with auto picked horizons from the input and conditioned data shown on it. The picks from the conditioned data are flat (obviously) and the picks from the input data vary randomly and with high spatial frequency about that flat line. Any surface picked from the conditioned data would therefore be much smoother than that picked from the input data.

The Basic Data Set

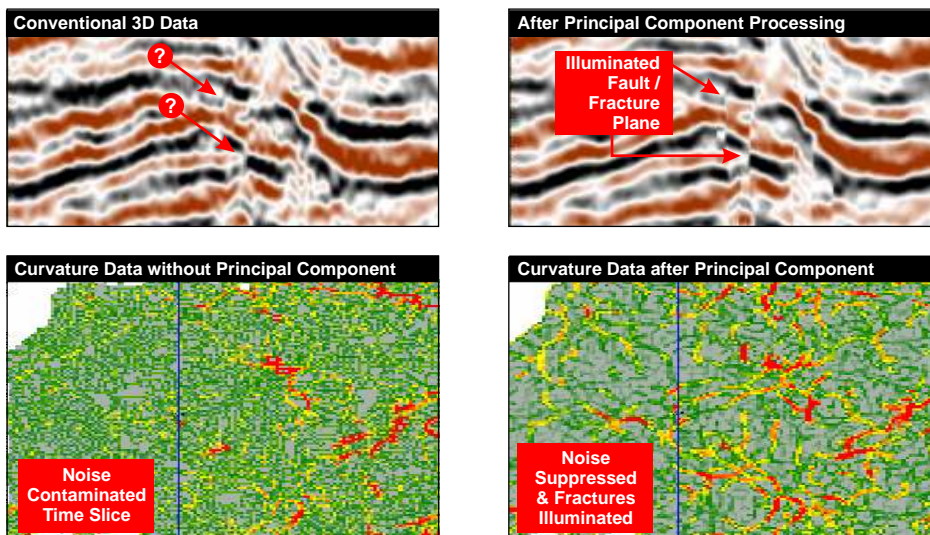
The benefits of this improvement in data quality are extensive. The primary benefit is a cleaner data set for interpretation in terms of continuity of events and smoothness of surfaces. This cleaner data set allows autopickers to operate more efficiently, requiring fewer inlines and crosslines to be picked to achieve results over a larger area, decreasing the time required for interpretation.

Secondly, the various types of noise affect not only the time of events, but the amplitudes as well. Both random and coherent noise interact constructively and destructively with the amplitudes of the reflected events. Because the PCA conditioning technique essentially builds a model of the ideal noise free sample at

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each location, the resulting amplitudes are more regular than those from the input data.

Subsequent Processing

The conditioned data set is also an improved input for further processing, one of the most obvious of which is

coherency. Coherency is a measure of the similarity of one trace to its neighbors. PCA conditioning produces traces which are more similar to their neighbors, but the structurally oriented filtering aspects prevents the operation from crossing legitimate breaks in the data. As a result coherency anomalies

are sharper and better defined after PCA conditioning. In several cases, coherency on the input data has been virtually useless whereas coherency on the conditioned data has shown well defined anomalies.

Curvature computations are highly dependent on the smoothness of the surface being analyzed. In the example we have shown, which is a case of very noisy data, the conditioned data will intuitively provide better curvature results. We have also done projects with highly continuous and apparently noise free data in which high lateral resolution curvature run on PCA conditioned data has less noise and better continuity of lineaments than the same curvature run on unconditioned data even though there was little visual difference between the two data sets.

A more subtle use of PCA conditioning allows geophysicists to expand the useable bandwidth of seismic data. Particularly for stratigraphic interpretations, interpreters prefer data that is rich in high frequency content, but, as seismic data is acquired, the earth works as a filter to attenuate high frequency information more than the corresponding low frequency data. The result may be thought of as a high signal-to-noise ratio for low frequencies and a low signal-to-noise ratio for high frequencies. Various processors have developed algorithms to strengthen the high frequencies to levels equal to those of low frequencies (spectral whitening). However, such efforts always increase noise at those frequencies. We have found that this type of noise may be successfully attenuated using PCA conditioning, thereby creating a noise-free data set with substantially higher frequency content than the input data.

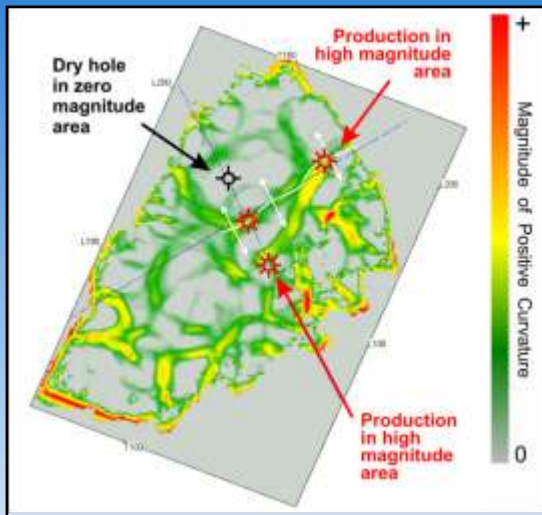
Conclusion

Principal component analysis conditioning is a powerful algorithm for removing noise from seismic data to provide cleaner results and better inputs for subsequent processing.

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* Survey size minimums may apply

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