Adding Texture Attributes to the 3-D Mix

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In a previous Geophysical Corner ("A New Approach to Stratigraphic Interpretation," September EXPLORER), we introduced a new set of seismic attributes that play an important role in extracting detailed stratigraphic information from seismic data.

The attributes in question were derived from a HorizonCube, an interpretation technique that provides fully interpreted seismic volumes where horizons are automatically tracked between a given set of framework horizons and faults.

This month, we go further and examine one other set of attributes – specifically, texture attributes, and how they can combine with HorizonCube attributes for 3-D segmentation.

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HEMSTRA

Neural network-based waveform segmentation workflows have proved to be a highly valuable instrument for seismic interpreters to quickly visualize seismic patterns in a relatively thin interval of interest (see figure 1). These networks compare the input vector (the waveform) with a set of pre-calculated vectors that represent segment (cluster) centers.

The resulting segmentation maps show for each position the winning segment center – and such maps often reveal patterns that can be interpreted in terms of geological features.

Neural network-based segmentation also can be performed in 3-D. However, this cannot be done by feeding the neural network with waveforms, as is done in the horizon-guided approach. This is because waveforms change along the application window while segment centers are fixed.

The solution to this problem is to feed the neural work with phase-independent seismic attributes, such as energy, or amplitude spectra derivatives.

There are not that many uncorrelated attributes that can be used effectively for 3-D segmentation, which may explain why 3-D segmentation is not as successful as horizon-guided waveform segmentation.

There are two particular sets of attributes, however, that can combine together to address the challenges of 3-D segmentation:

- Attributes derived from a HorizonCube and that were described in the previous article.
- Texture attributes.

Texture attributes are popular in image

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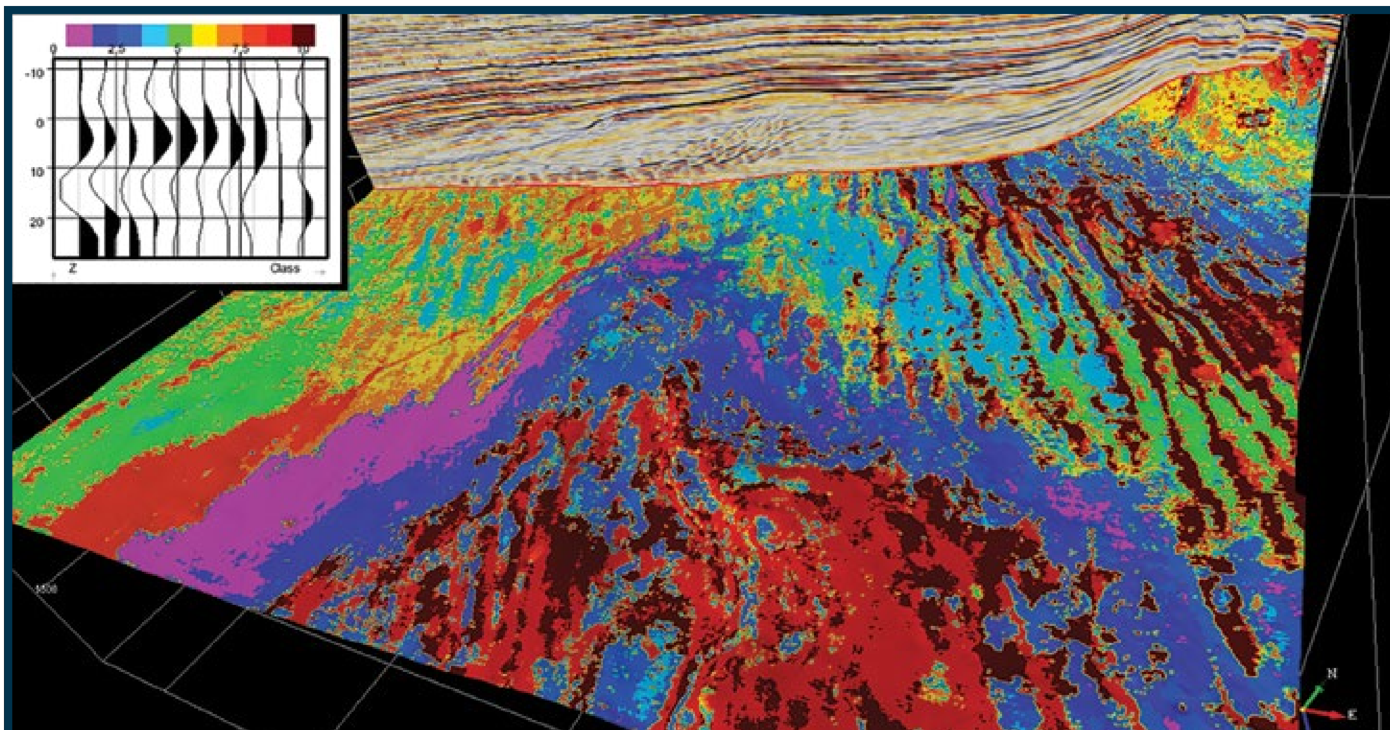

Figure 1 – A horizon-guided UVQ waveform segmentation map.

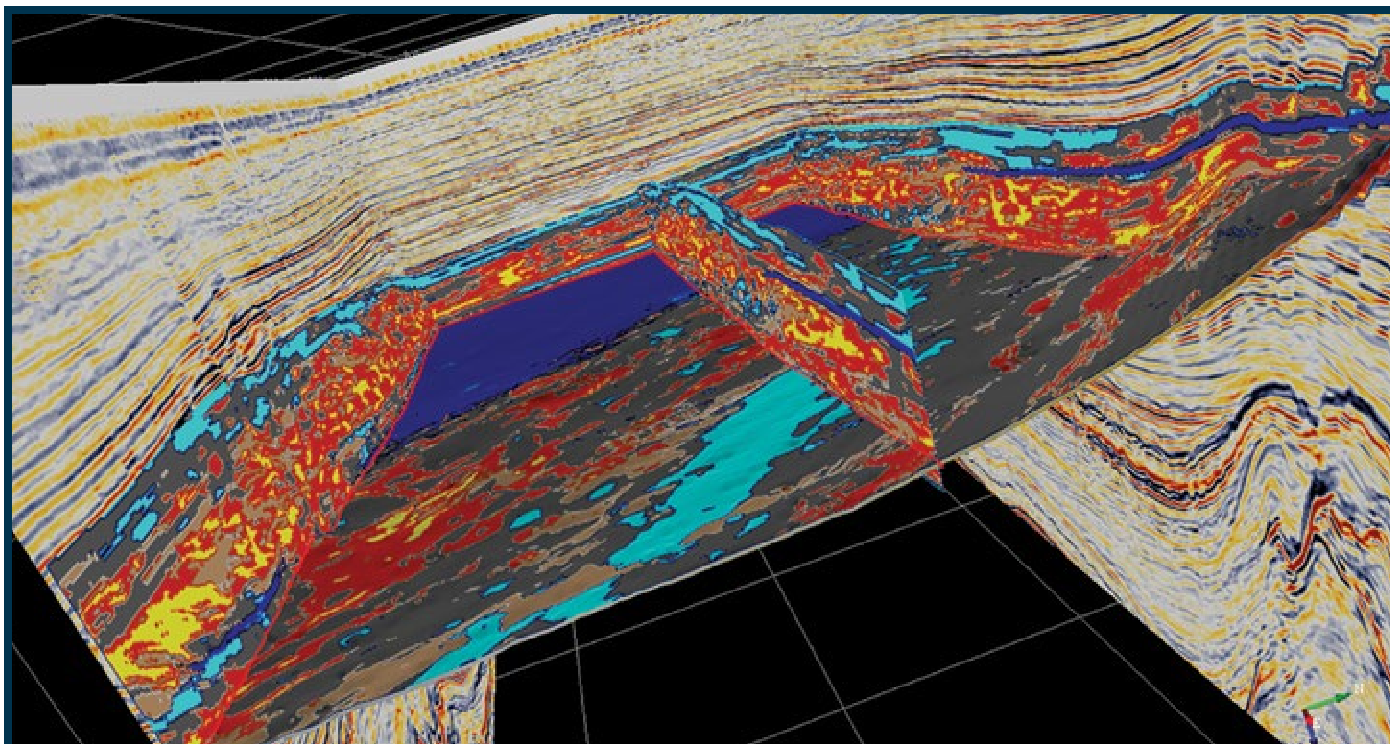

Figure 2 – A seismic display for UVQ segmentation using both texture and HorizonCube attributes.

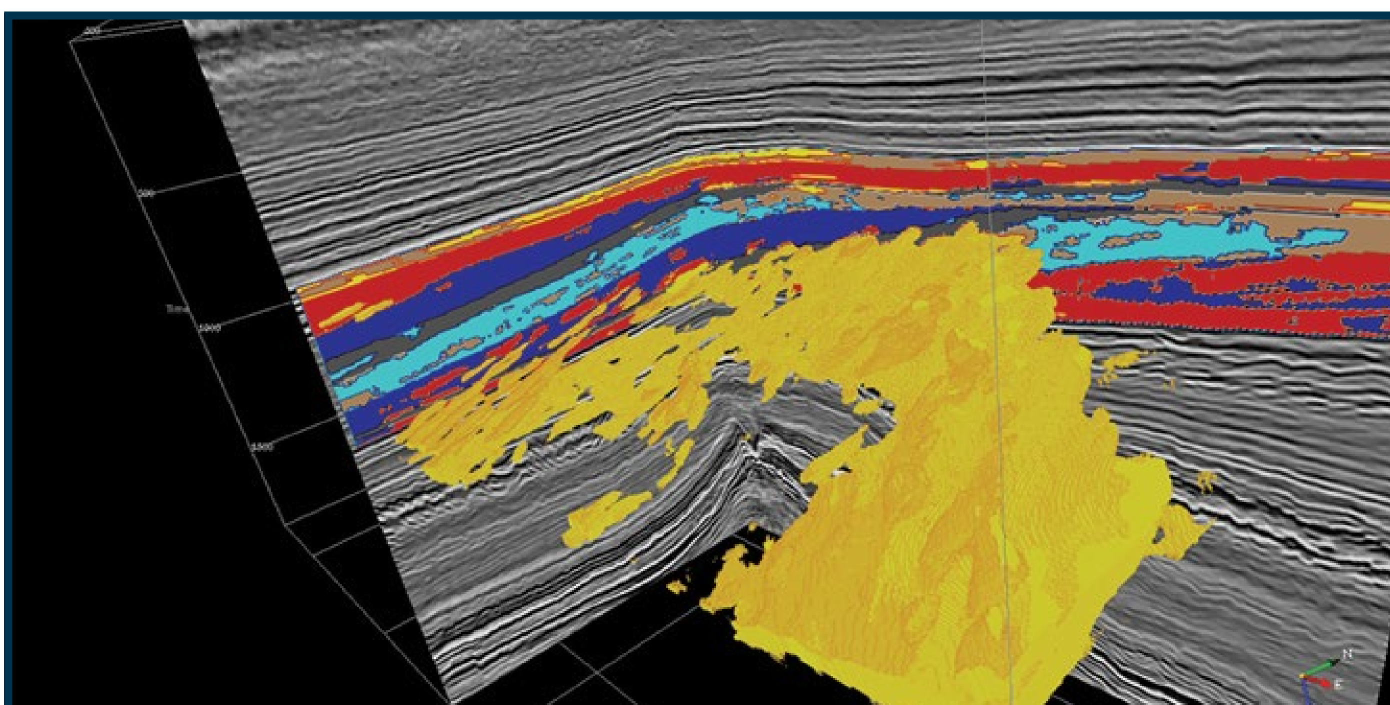

Figure 3 – Systems tracts used as bias for UVQ segmentation.

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processing and are used in seismic interpretation to carry out seismic facies analysis and highlight geo-morphological features. They originate from image analysis and are based on the Grey Level Co-occurrence Matrix (GLCM), which describes the relationship between pixels and was developed to capture the roughness or smoothness of an image.

A GLCM is a 2-D matrix of N x N dimensions representing the amplitude values of the reference pixel versus the amplitudes of the neighboring pixel. The matrix is filled by comparing each amplitude in the input area (volume) with its direct neighbor and increasing the occurrence of the corresponding matrix cell.

This is repeated for all amplitude pairs in the input cube, which then are converted into probabilities.

The GLCM thus captures how probable it is to find pairs of neighbouring amplitudes in the area (volume) around the evaluation point.

Texture attributes are computed in two steps:

- First, the GLCM is computed for an area (volume) around the evaluation point.
- Second, a statistical property from the GLCM is returned.

The GLCM input volume can be "dip-steered," meaning that the input follows the stratigraphic layering, which results in sharper attribute responses for dipping strata.

Three groups of texture attributes are computed from the GLCM:

- Contrast (contrast, dissimilarity and homogeneity), where measurements are calculated through the use of weights related to the distance from the GLCM diagonal.
- Orderliness (ASM, energy and entropy), where interpreters measure how regular the pixel values are within the window.
- Statistics (mean, variance and correlation), which are derived from the GLCM.

In each group, the attributes are highly correlated.

Through the use of both texture and the already described HorizonCube attributes, seismic interpreters now have two new groups of attributes that can be used as inputs to UVQ (Unsupervised Vector Quantization) networks for 3-D seismic facies analysis.

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Figure 1 (page 46) shows a horizon-guided UVQ waveform segmentation map that captured the seismic response below a maximum flooding surface in a wave-dominated Pliocene deltaic setting, offshore Netherlands. The UVQ network was trained to segment the interval of interest into 10 segments.

The UVQ segmentation map reveals several key geomorphological patterns that help to understand the depositional environment and the influence of salt tectonics.

The NW-SE oriented dark brown-red features on the right are sand ridges of 10-20 meters in height, developed parallel to the coast. These features are analogous to present day deposits observed along the Dutch coast.

Furthermore, NE-SW oriented deepwater channel systems are recognized (purple-red, on the left). These narrow channel-levee systems are developed as a result of halo kinetic movement of Zechstein salt in the northeast (upper right) corner of the image. Up-dip these channels cross-cut the sand ridges while down-dip they meander and bifurcate into the basin, where turbiditic deposits could be developed.

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Figure 2 shows a seismic display for UVQ segmentation using both texture and HorizonCube attributes with energy, variance and correlation for the texture attributes; density and thickness for the HorizonCube attributes; and dip-steered energy as the input attribute for the neural network.

There are six classes in the illustration with it possible to see different behaviors in different areas.

If interpreters have carried out a systems tracts interpretation, they can use this interpretation to more or less force the segmentation to adhere to one's own interpretation through a biased 3-D UVQ as seen in figure 3.

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In addition to texture and energy attributes, figure 3 illustrates how a systems tract's interpretation is used as bias for UVQ segmentation with, in this case, HorizonCube attributes not used as input.

The illustration shows the impact of using systems tracts as an input and the final segmentation. These classes (such as the yellow class) can then be extracted and seen in 3-D, allowing the interpreters to better define geobodies.

HorizonCube attributes are particularly useful for identification of stratigraphic features – such as pinch-outs, clino-forms, unconformities and condensed sections – whereas texture attributes play an important role in seismic facies analysis and in highlighting geo-morphological features.

When combined together, HorizonCube and texture attributes play an important role in 3-D segmentation and in identifying and mapping potential reservoir lithology in seismic data.

(Editor's note: By AAPG member Farrukh Qayyum, Paul de Groot and Nanne Hemstra all are with dGB Earth Sciences, Enschede, Netherlands.)