Visualizing Anisotropy in Seismic Facies Using Stratigraphically Constrained, Multi-Directional Texture Attribute Analysis*

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Abstract

Texture attributes originate from image processing where they were developed to capture the roughness or smoothness of an image by describing the relationship between pixels (Haralick et al., 1973). In seismic interpretation texture attributes are used in seismic facies analysis and to highlight geo-morphological features (e.g. Vinther et al., 1996; Gao, 2008, 2009, 2011; West et al., 2002; Chopra and Alexeev,, 2006, Yenugu et al., 2010; de Matos et al., 2011, de Groot et al., 2013).

Texture attributes are based on the Grey Level Co-occurrence Matrix (GLCM), a 2D matrix of N x N dimensions representing the amplitude values of the reference pixel versus the amplitudes of the neighbouring pixel. The original GLCM calculation was developed for 2D images. The matrix is filled by comparing each amplitude in the input area with its direct neighbour and increasing the occurrence of the corresponding matrix cell. This is repeated for all amplitude pairs in the input area, which are then converted into probabilities. The GLCM thus captures how probable it is to find pairs of neighbouring amplitudes in the area around the evaluation point.

Three groups of texture attributes are computed from the GLCM: Contrast (contrast, dissimilarity and homogeneity) where measurements are calculated using 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; and Statistics (mean, variance and correlation) that are derived from the GLCM. In each group, the attributes are highly correlated.

Introduction

In seismic attribute analysis, we often work with 3D seismic data. It is therefore, necessary to adapt the 2D GLCM calculation and introduce the third dimension (e.g. Eichkitz et al., 2012b, 2012c, and 2013). Other workers in seismic texture attribute analysis have also filled the

GLCM matrix with information from 3D input cubes but to our knowledge, they use a two-dimensional approach, or they restrict the GLCM calculation to a few space directions only.

The method described in this paper differs from earlier work in two ways: firstly, the method allows analyzing seismic data in 13 space directions. In three dimensions, any sample point has 26 neighbouring sample points. These neighbouring sample points are aligned in 13 space directions. In the method, each direction can be used in single plane calculations, or it is possible to combine several directions in the GLCM calculation. The second innovation is that the method allows GLCM input planes to be 'dip steered' meaning that the input warps along the stratigraphic layering, which results in sharper attribute responses for dipping strata.

This combination of directional analysis and dip-steering opens the way for texture attributes to be used in the study of anisotropic behaviour of stratigraphic intervals. In this paper, we will first discuss the effect of dip steering on the computation of texture attributes. Next, we describe the effect of directional analysis by computing texture attributes in each of the 13 principle spatial directions.

Dip-Steered Analysis

Dip steering is a process in which seismic reflections are followed by auto-tracking a pre-calculated dip field (e.g. de Rooij and Tingdahl, 2002). The auto-tracker starts at the evaluation point and follows the local dip and azimuth to arrive at the next trace. At this position, it updates the local dip-azimuth information to reach the next trace and so on. This process is used among others in structurally oriented filters, in the creation of HorizonCubes (consisting of a dense set of auto-tracked horizons) and to compute multi-trace attributes such as dip-steered texture attributes. Figure 1 shows the effect of dip steering on a XX texture attribute. It clearly shows that in areas with dipping strata the attribute response follows the seismic reflection patterns better when dip steering is used.

Directional Analysis

The directional analysis workflow is explained at the hand of a real data example from the Vienna Basin. For this case study, the results of the GLCM calculations are also compared to enhanced semblance-based coherence depth-slices (Eichkitz et al. 2012a). With the help of GLCM-based attributes, it is possible to highlight the same channel structure as in the coherence cube. Furthermore, the GLCM attributes reveal information about the channel interior, which cannot be seen in the coherence. Calculations in specific space directions indicate an anisotropy effect in the data. Note that "anisotropic" in our context refers to the difference in attribute response due to directionality in the attribute only and does not imply anisotropic (elastic) properties of the rock, though potentially the GLCM attribute can be used to detect such as well. In Figure 2, the results of GLCM-based Energy attribute for all 13 single directions are displayed (Figure 3). Clearly, the channel is more pronounced in several directions (e.g. azimuth 0° and dip 0°), whereas in some directions (e.g. azimuth 0° and dip 90°) the channel is poorly illuminated. To enhance these anisotropy effects it is possible to calculate difference maps to visualize the major and minor anisotropy directions.

In this workflow, it is possible to combine several directions (in inline, crossline, timeslice direction) or to calculate all these directions at once. The calculation in multiple directions suppresses noise in the data and the channel structure is better illuminated. However, the combined

calculations might miss subtle features that can be seen in single direction calculations. Especially, any anisotropy effects within the data are not highlighted.

Conclusions

This paper described the effects of dip-steering and directional analysis on texture attributes. The input in this case was seismic amplitude but the method can be applied to any seismic attribute volume. The directional method enables texture attributes to analyze anisotropic effects in seismic attributes while dip steering ensures that the attribute response focuses on stratigraphic analysis.

Acknowledgements

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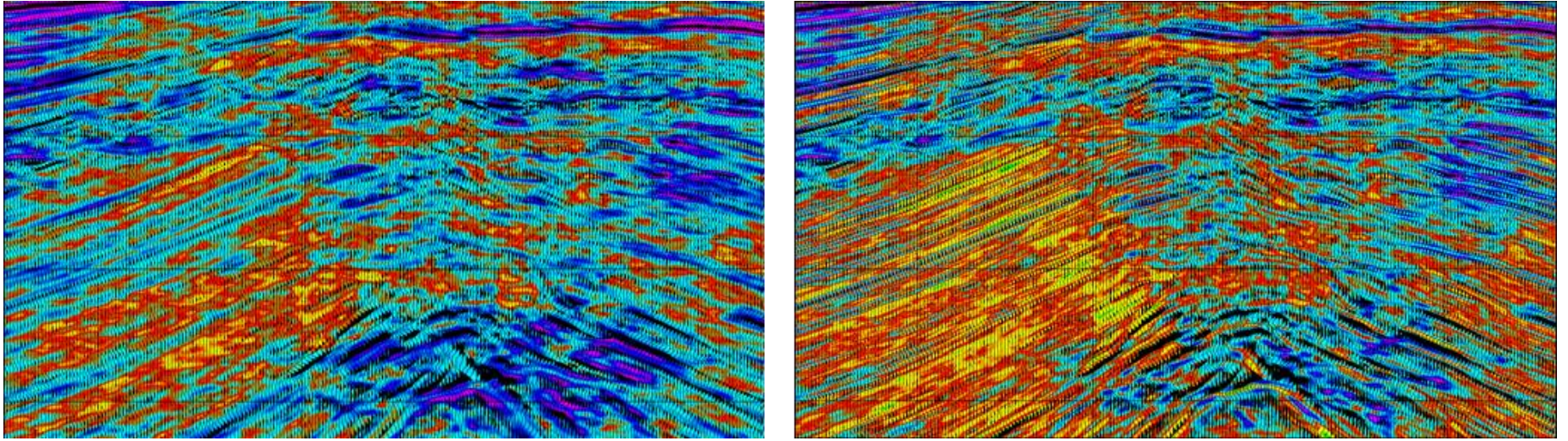
Figure 1. GLCM size 16x16, time gate -8, +8, step 3, 3 texture attribute without dip-steering (left) and with dip-steering (right).
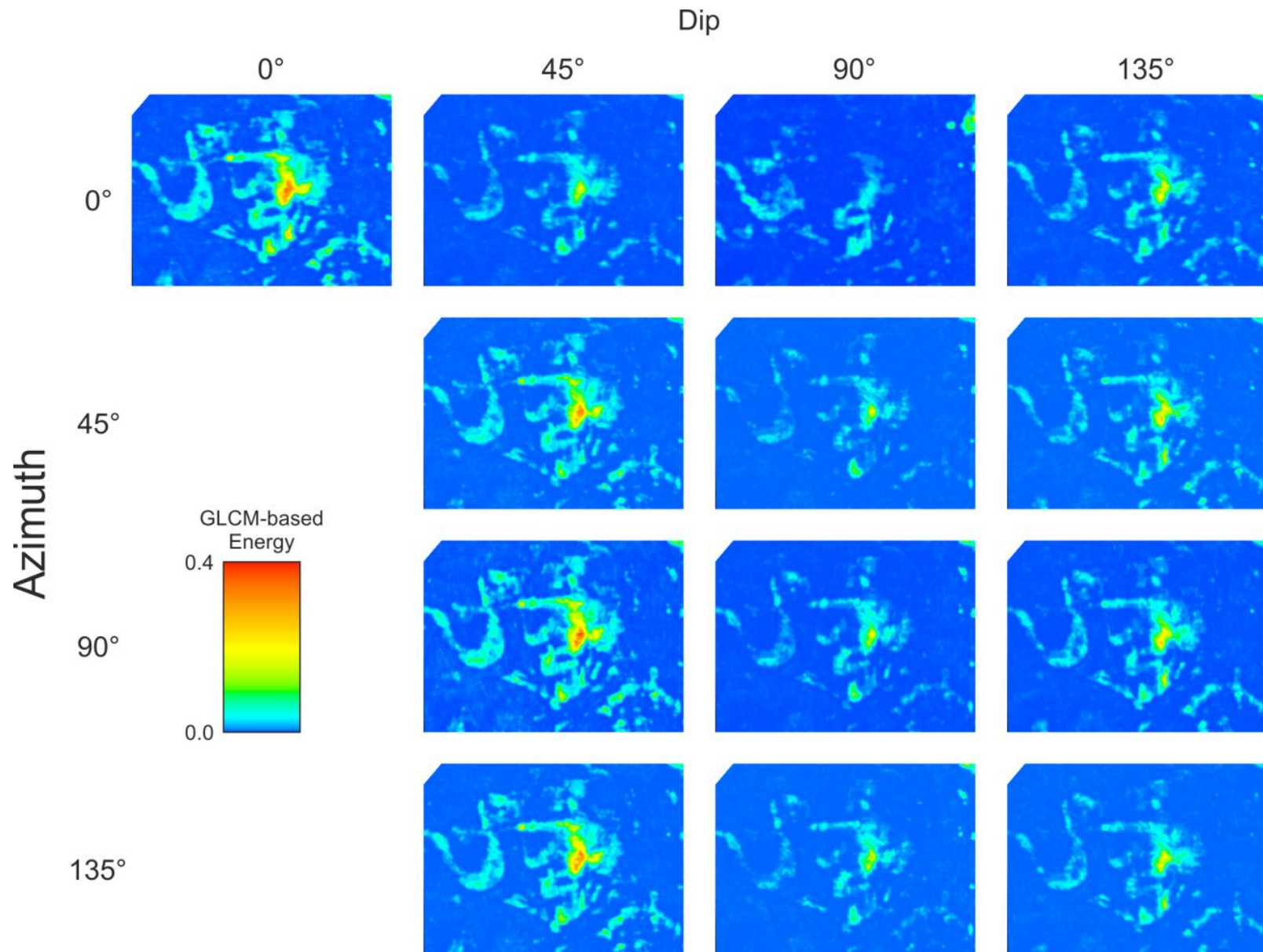
Figure 2. Results for the calculation of direction based GLCM calculation. Calculation of the GLCM-based Energy attribute used a window size of 3 x 3 x 11 samples and 128 grey levels. The image shows that depending on the direction used different features of the channel are highlighted.
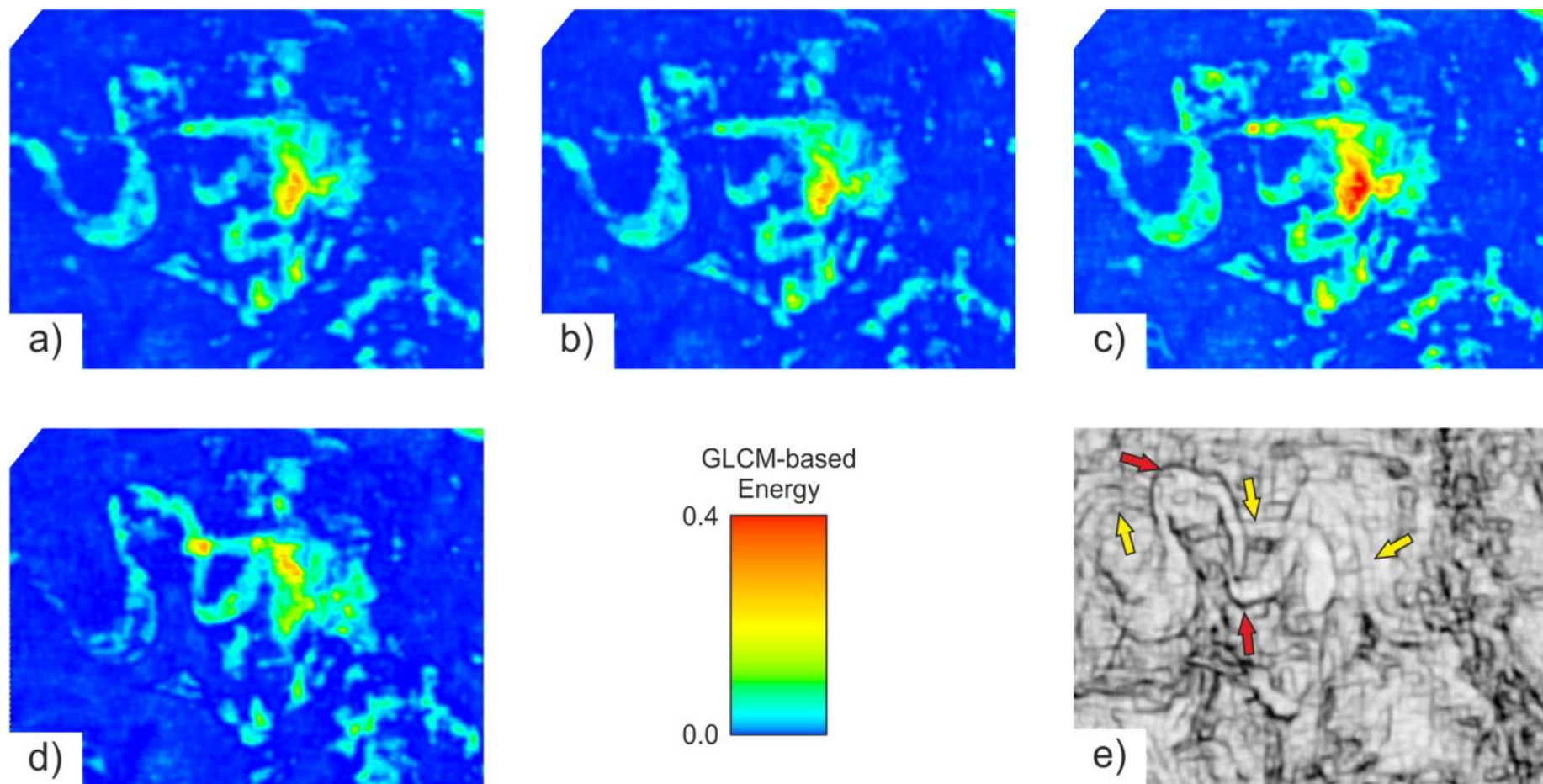
Figure 3. In the developed workflow, it is also possible to combine several directions for the computation of GLCM-based attributes. In (a) the result for combined calculation in Inline direction (all directions with azimuth 0°) is displayed. In (b) the result for combined calculation in Inline direction (all directions with azimuth 90°) is displayed. In (c) the result for combined calculation in Time/Depth slice direction (all directions with dip of 0°) is displayed. In (d) the result for combined calculation in all directions is displayed. For comparison of the results in (e) the same depth slice with a semblance-based coherence (Eichkitz et al., 2012a) is displayed. Combining several directions or all directions for the GLCM calculation gives smoother results than single direction calculation, but subtle features might be missed by this approach.