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3D textural attributes based on the grey level co-occurrence matrix as an aid to common seismic attribute interpretation

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Workflow for 3D calculation of grey level vo-occurrence matrix-based attributes

The grey level co-occurrence matrix (GLCM) describes how often different combinations of pixels brightness values occur in an image (fig. 1 and fig. 2). The numbers of co-occurrences are displayed in a square matrix. Based on this matrix several textural attributes can be calculated. Originally, the GLCM as developed by Haralick et al. (1973) was used for image classification. Since then, it has been successfully applied for classification of satellite images, sea-ice images, pictures, and medical pictures like computer tomography. For the classification of seismic data the GLCM is still a minor topic. In the last two decades several authors have described the applicability of GLCM for classification of seismic data (Vinther et al. 1996; Gao 1999, 2003, 2007, 2008a,b, 2009, 2011; West et al. 2002; Chopra and Alexeev 2005, 2006a,b; Yenugu et al. 2010; de Matos et al. 2011; Eichkitz et al. 2012b, 2012d, 2012e). We developed a workflow (fig. 3) for full 3D GLCM calculation that follows the works by Tsai et al. (2007) and by Lai et al. (2008). The developed workflow is applied onto 3D seismic data and the results of the GLCM calculation are compared to common coherence calculations (Eichkitz et al., 2012a, 2012c).

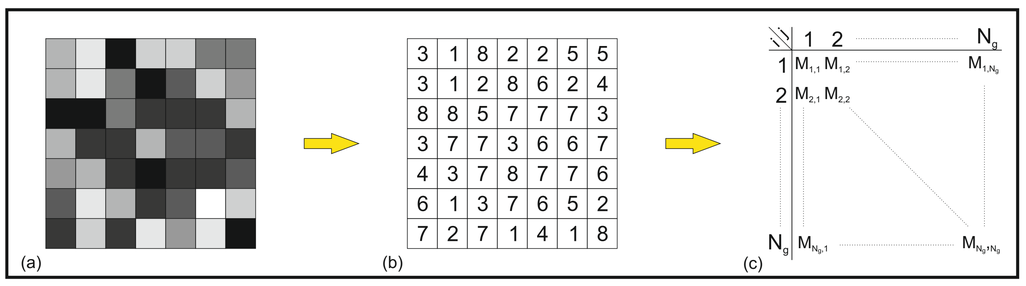

Figure 1: Principal work steps for the calculation of grey level co-occurrence matrix-based attributes. The initial image or dataset needs to be transferred into a grey scale image (a), which can be represented by discrete values (b). The number of co-occurrences of pixel pairs for a given search window are counted and a grey level co-occurrence matrix (c) is established. Based on this co-occurrence matrix several attributes can be calculated.

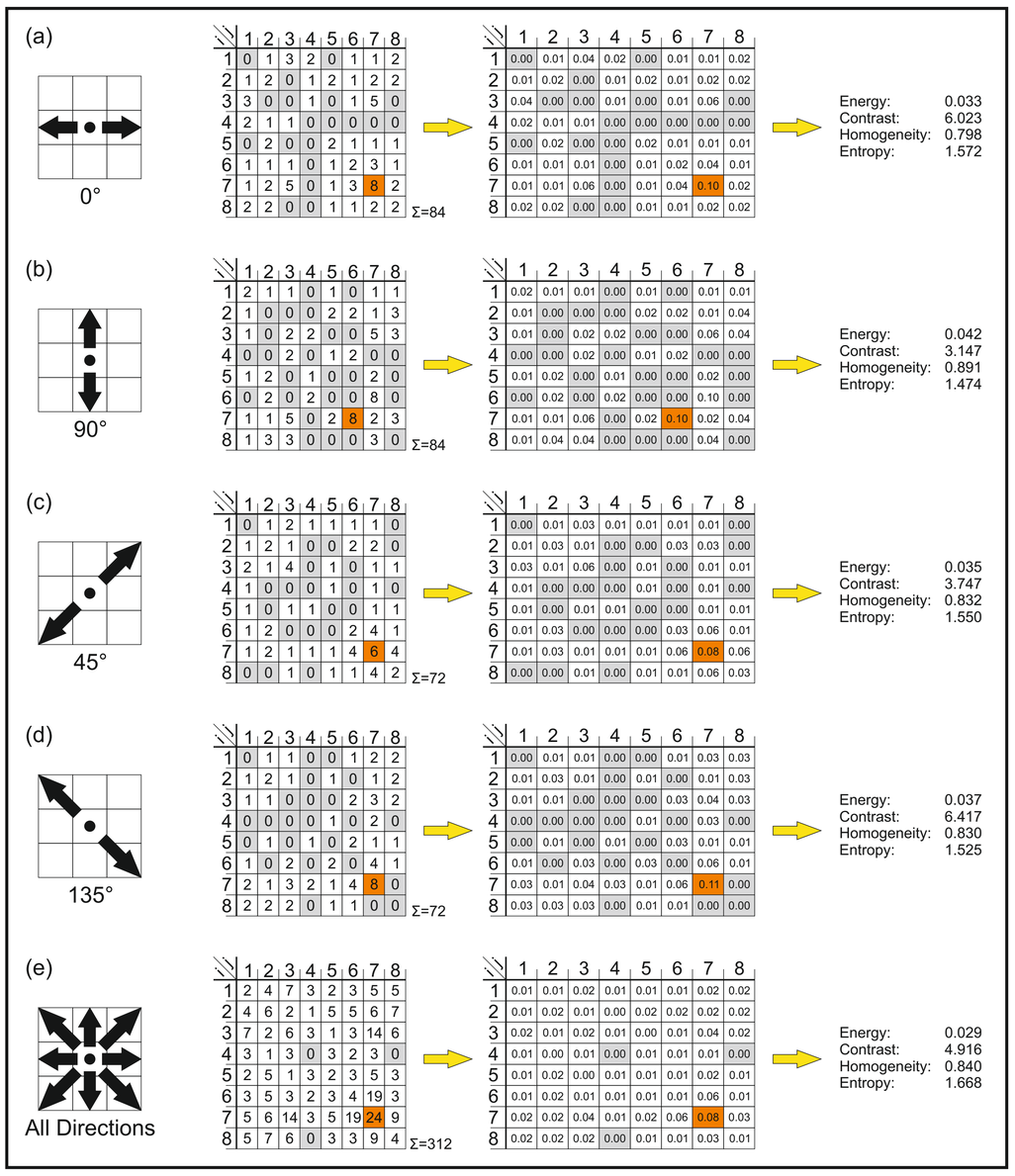

Figure 2: Schematic for the calculation of grey level co-occurrence matrix-based attributes using eight grey levels. In this example the grey level co-occurrence matrices are determined for the horizontal (a), the vertical (b), the 45° diagonal (c), the 135° diagonal (d), and for all directions at once (e). The input for the calculation is the image from figure 1. The first step in calculation is the determination of co-occurrences (column 2). Zero entries are marked in grey and the highest value of each matrix is marked orange. Clearly, one can observe that calculations in single directions lead to sparse matrices. The GLCM is normalized by the sum of the elements to get a kind of probability matrix (column 3). Finally, the probabilities are used for the calculation of GLCM-based attributes. In column 4 the results for Entropy, Contrast, Homogeneity, and Entropy are shown.

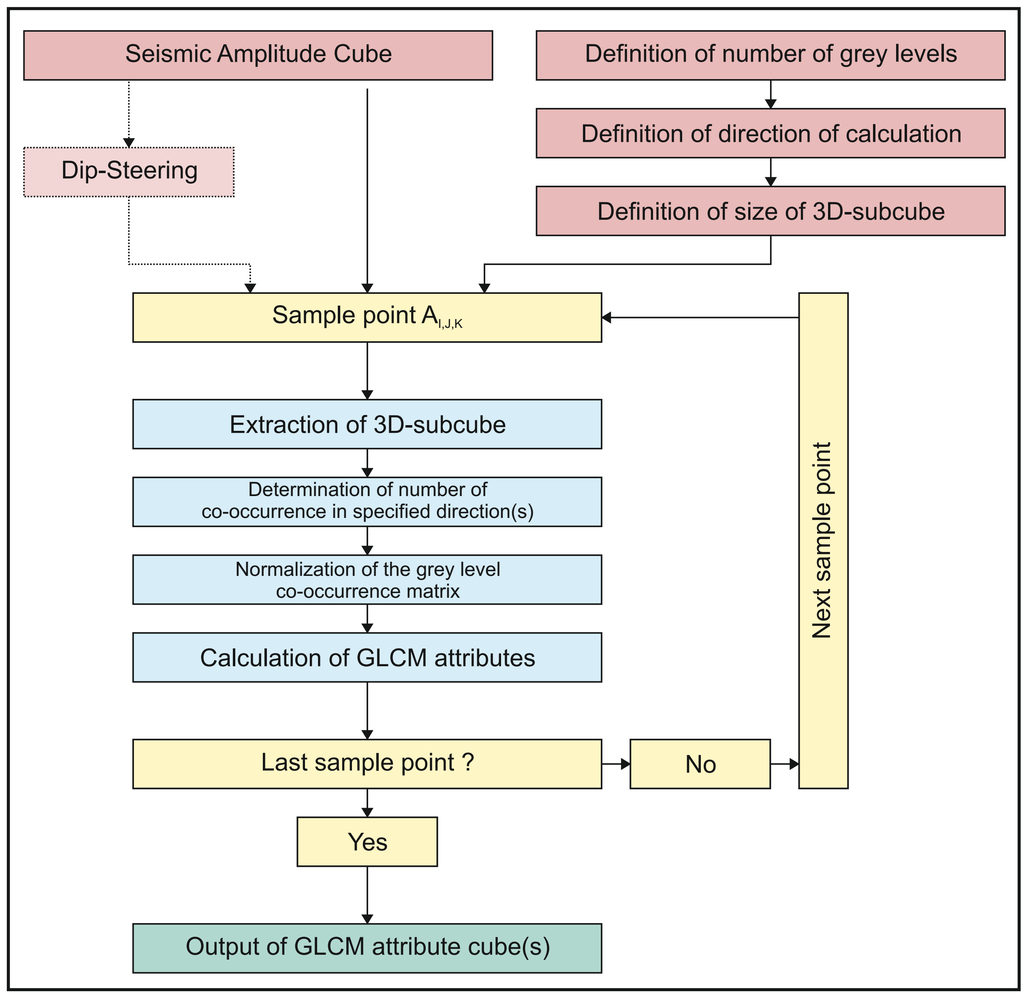

Figure 3: Workflow used for the calculation of GLCM-based attributes. In principal it is possible to divide the workflow into three parts. The first part is data input and definition of parameters (red boxes). The second part is the extraction of a 3D-subcube, the establishing of a GLCM, and the calculation of the GLCM attributes for the specified subcube (blue boxes). The third part describes the loop over all sample points within the input cube (yellow boxes). As final result from this workflow a set of GLCM-based attribute cubes is generated (green box).

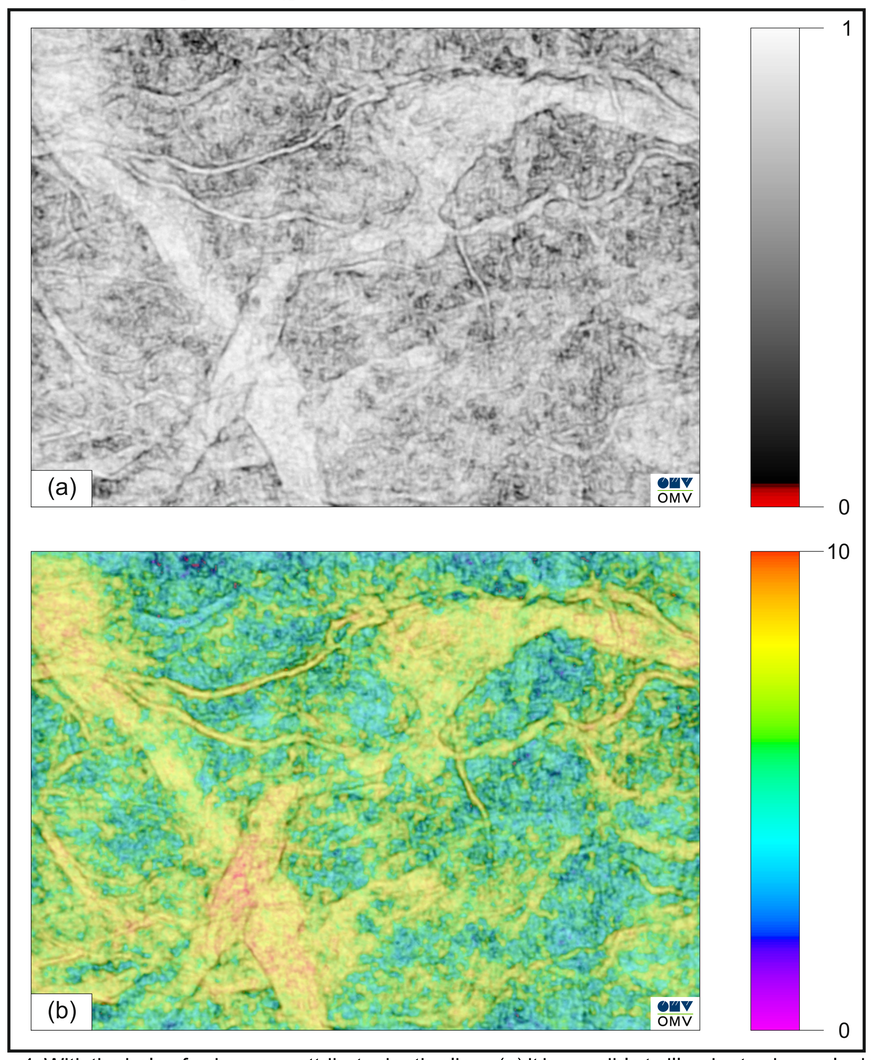

Figure 4: With the help of coherence attribute depth-slices (a) it is possible to illuminate channel edges. The application of GLCM attributes (b) – Entropy in this case – can also illuminate the channel interior. Thus, this method allows the direct extraction of channel geobodies, which can then be used for reservoir modeling.

Conclusion

We tested various GLCM attributes (Energy, Contrast, Entropy, Homogeneity, Cluster Shade, Cluster Prominency, Dissimilarity, …) on their applicability to detect structural features as faults or fractures, and depositional facies as channels. In fig. 4 the results for a GLCM attribute (Entropy) in comparison with a depth-slice of a semblance-based coherence cube is shown. In the coherence depth-slice clearly channel structures are visible. Especially the channel edges are detectable. But based on these results it is hardly possible to directly extract channel geobodies. The GLCM attributes on the other hand provide information on the channel interiors. Therefore, we can delineate the geometry of channels not only manually depth-slice by depth-slice, but directly delineate the spatial distribution of channels. Thus, this is a volumetric representation of the channels itself and can therefore be used to extract geobodies.

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