Using Wavelet Transform and Self Organizing Maps for Seismic Reservoir Characterization of a Deep-water Field, Campos Basin, Offshore Brazil

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Introdction

Seismic facies analysis is not a deterministic and simple task. Usually, facies analysis is performed through the following steps [1]:

1. Geological oriented spatial and temporal segmentation of seismic traces (input space);
2. Seismic attributes selection (variable space);
3. Choosing the optimal number of classes (facies) and algorithm iterations;
4. Training and classification of the selected attributes using some statistical or neural networks methods (pattern space);
5. Building and interpreting facies map.

Normally, the geological oriented spatial and temporal segmentation should be carefully done, because any horizon interpretation error could lead to wrong or very noisy facies results. The attributes selection is another complex task, because they should be physically consistent and statistically independent. It's common to use the whole seismic trace amplitudes around the region of interest [2].

Nowadays, Self Organizing Maps (SOM), or Kohonen Maps [3], has become one of the most popular tools to build seismic facies maps [4]. But, it's still empirical how to choose the number of classes and the best seismic attributes to discriminate geological features from seismic data.

This project presents a new alternative to extract seismic pattern attributes and a new methodology to build seismic facies maps. We propose using Wavelet Transform to identify singularities in each geological oriented segment of the temporal seismic trace and then using SOM in a two-level approach [5]. To illustrate this technique it was applied to real data from a deep-water field in the Campos Basin, Brazil.

Seismic Trace Singularity Detection with Wavelet Transform

Signal transitions can be described using its local degree of regularity, which can be derived from a multi-scale evaluation of the wavelet coefficients that are caused by the transitions. Mallat and Hwang [6] showed that the amplitude evaluation along the modulus maxima line formed by the undecimated wavelet transform, also called Wavelet à Trous, can be used to characterize signal singularities, as follows:

1. Decompose the signal using wavelet à trous;
2. Find the Wavelet Transform Modulus Maxima Line (WTMML), checking if all its points are in the cone of influence;
3. Evaluate the amplitudes along the modulus maxima line (WTMMLA).

Figure 1 illustrates that procedure applied to two different synthetic traces, traces 06 and 10, obtained from a synthetic wedge model and the resulting WTMMLA confirms they can be used as different patterns for a classification system. WTMMLA can also be viewed, in a very simple form, as the ridges of the Continuous Wavelet Transform.

The WTMMLA has been used to obtain the Hölder exponent as another seismic attribute [7], but, in this project, using the whole WTMMLA curve was preferred as singularities patterns.

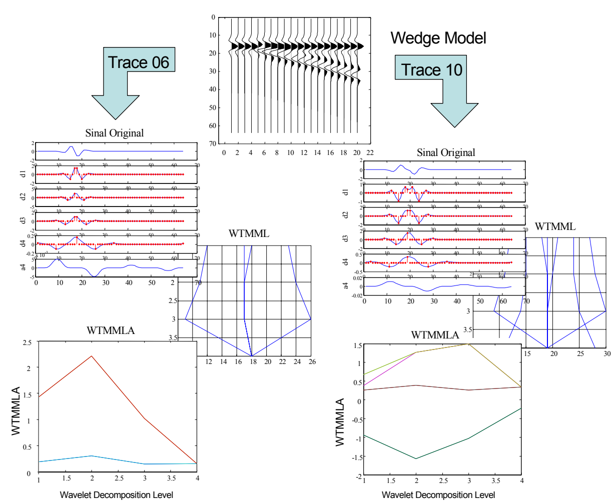

Figure 1: Synthetic signals; its wavelet à trous decomposition; WTMML and WTMMLA.

Self Organizing Maps (SOM) and Seismic Facies Analysis

SOM, besides producing a similarity graph of input data, it's an effective tool for the visualization and clustering of high-dimensional data. Basically, it converts the nonlinear statistical relationships between high-dimensional data into simple geometric relationships of their image points on a lower-dimensional display, usually as a regular two-dimensional grid of nodes. Thus, the SOM can be interpreted as a topology preserve mapping from input space onto the two-dimensional grid of map units.

The obtained grid can be used as a powerful qualitative visualization tool for showing different features of the data, as their cluster structure. A useful tool to evaluate the cluster structure is the Unified Distance Matrix - U-matrix, which gives the distances between prototype vectors of neighboring map units. Typically, a red color indicates long distances and a blue color indicates short distances. This gives an impression of "mountains", which divide the map into "fields" such as dense parts or clusters. Each cluster represents a different class.

Figure 2 illustrates the SOM applied to 32 seismic trace amplitudes around the base of reservoir horizon in a deep-water field. K-means algorithm was used to cluster the SOM map and the minimum Davies-Bouldin index was used to identify the number of clusters [5].

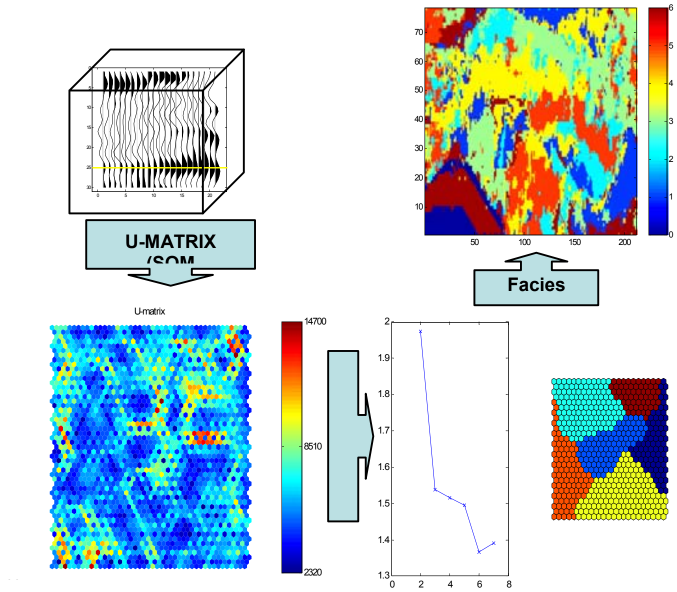

Figure 2: **Facies analysis methodology**. This example uses 32 seismic amplitudes around the reservoir bottom as an input attribute. (a) seismic amplitudes; (b) The U-matrix of a 27x23 SOM map; (c) Davies-Bouldin index with a 6 class minimum; (d) clustering of SOM map and (e) facies map.

Wavelet transform (WTMMLA) and Kohonen Map (SOM)

The method proposed here brings together the wavelet bi-orthogonal seismic trace expansion with the clustering characteristics of the SOM and K-means, to obtain an interesting new way to cluster seismic facies. They are as follows:

1. Segment each seismic trace around a geological oriented region.
2. Find the Wavelet Transform Modulus Maxima Line Amplitudes(WTMMLA) using the desired number of levels.
3. Visualize the self-organizing map (SOM) formed using WTMMLA as the seismic attributes input space.
4. Cluster the SOM using K-means, or other clustering algorithms, with as many clusters as shown on the SOM map or use some empirical metrics as the Davies-Bouldin index.
5. Construct and interpret the facies map.

As an example, the method proposed was applied to a 3D seismic data from a deep-water field in the Campos Basin, offshore Brazil and the result using only the two largest WTMMLA (illustrated in Figure 3) seems consistent, showing a very good cluster definition in the SOM map similar to already used petrophysical and other analysis [8].

The whole algorithm, from SEGY files and horizon reading to seismic maps visualization, was implemented using Matlab from Mathworks and the SOM Toolbox from Helsinki University of Technology.

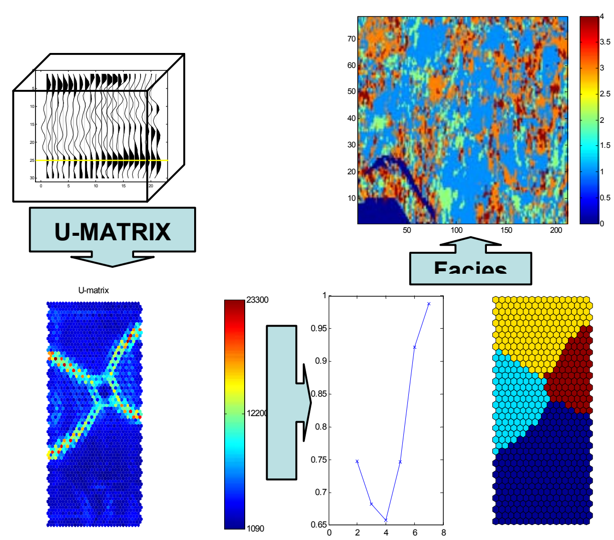

Figure 3: **Facies analysis methodology**. This example uses the two largest WTMMLA as input attributes. (a) seismic amplitudes; (b) The U-matrix of a 39x16 SOM map; (c) Davies-Bouldin index with 4 classes minimum; (d) clustering of SOM map and (e) facies map.

Conclusions

Results have shown that the new method proposed for seismic facies analysis can be an alternative way to 3D or 4D seismic reservoir characterization. Particularly, we propose a new approach to extract reliable seismic attribute as input data for self-organizing map visualization and clustering of an entire volume of seismic data of a deep-water field in theCampos Basin, offshore Brazil.

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