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Neural Network Application of Curvature Attribute for Fracture Analysis

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Summary

Application of Neural Networks analyses has recently attracted more attention among geoscientists trying to apply mathematical knowledge to gain more geological information from seismic data (2013). Neural networks are one of the most efficient ways to recombine multiple input attributes and achieve a high quality extraction of a target feature or rock property from seismic data. It is a good tool to enhance a geological interpretation of seismic data. This paper presents a new application of neural network method to combine curvature attributes, mainly most positive curvature attribute, with different step-outs for discontinuity analysis using the North Sea 3D dataset (F3 block).

Introduction

F3 block is in the Dutch sector of the North Sea.The block is covered by 3D seismic that was acquired to explore for oil and gas in the Upper Jurassic – Lower Cretaceous strata. The upper 1200ms of this 3D consists of reflectors belonging to the Miocene, Pliocene, and Pleistocene. An intra-Pliocene horizon was used for testing the method (see Fig. 1).

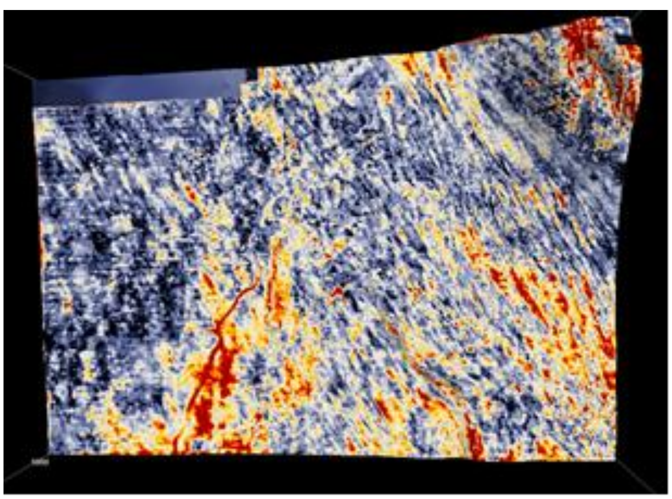

Figure 1 Display of horizon Flooding Surface 1 used to test the method.

Curvature attribute analysis is often used to detect structure and/or stratigraphic discontinuities such as faults below seismic resolution, shear zones, channel edges and strand-plains. Unfortunately the 3D data often carries an acquisition footprint that can mask these features or make them undistinguishable on a curvature map. Many authors have described ways to use curvature with variable spatial extents to analyze and image these features. Curvature attribute analysis, specifically, most positive curvature, was used to map fractures, which in turn were the input for neural network based analysis. Results of the neural network analyses reveal more details about the fractures and allow us to differentiate between valid data and acquisition footprints more easily.

Method

Roberts (2001) defines curvature as a two-dimensional property of a curve that describes how bent a curve is at a particular point in the curve, i.e. how much the curve deviates from a straight line. The same concept is used to describe the curvature of a surface. Curvature is measured on the curve which is the intersection between a plane and the surface. Since this can be done in numerous ways, there is an infinite number of curvature attributes that can be calculated for any plane. The subset implemented here relates to the most useful subset of curvatures that are defined by planes that are orthogonal to the surface and which are called normal curvatures. A positive curvature corresponds to an anticline and a negative curvature to a syncline. A flat plane has zero curvature. Curvature in general is the second derivative and is non-dependent on surface orientation and it can delineate many more surface lineaments without suffering from the problem of so-called dip saturation.

Most positive curvature returns the maximum positive curvature from the infinite number of Normal Curvatures that exist. The attribute helps to reveal faulting and other geological lineaments. The magnitude of the lineaments is preserved but the shape information is lost. This attribute can be compared to first derivative- based attributes (dip, edge, and azimuth) but will return different values based on the aperture (step-out).

Various types of neural networks have been applied successfully in a variety of scientific and technological fields. Examples include applications in industrial process modeling and control, ecological and biological modeling, and sociological and economical sciences and medicine. Within the exploration and production world, neural network technology has been used since 1998 and is applied to geologic log and seismic attribute analyses (Brouwer, 2011).

Neural Networks used for seismic object detection can be divided into two types: unsupervised (model driven) and supervised (i.e. user driven). Although the plan was to use a supervised neural network on existing faults to generate the Fault Cube, testing showed that the method was unsuccessful due to lack of clear definitions for traced faults. Alternatively, un-supervised neural network approach was made for the volume.

In curvature analysis, a critical aspect is the spatial extent for each curvature calculation. A smaller spatial extent will reveal features while the larger spatial calculations will reveal a different set of geological details. Usually, a curvature attribute highlights the acquisition footprints while other lineaments are obscured. The interest of the interpreter is to have all these curvature information classified so they could be separated to investigate each type of lineament.

The Most Positive Curvature attribute provides the maximum correlation to the strandplains within the 3D dataset. We generated Most Positive Curvature attributes using step-outs of 5x5, 7x7, 9x9, 11x11 and 15x15 samples in the XY domain. The 15x15 filter highlighted the mega-trends while the smaller 5x5 step-out showed locally associated features. As the acquisition footprints repeat in the X and Y direction, they will offer different values at different apertures while other linements will re-inforce based on their strength.

The five volumes investigated were then classified using a multi-volume un-supervised neural network approach. The process starts with choosing 5000 random samples between two horizons covering a slice of about 100 ms thick. These 5000 samples represent a set of various curvature values from all five volumes. The neural network approach is given 10 classes to create discrete sets. This volume can also be known as a hybrid volume and it generates a classified output. The classified volume or Most Positive Classfied Curvature Cube (MPC^3) can differentiate lineaments from the background such as acquisition footprints.

Examples

The following figures show the application of MPC^3 to the F3, 3D data-set. The westward dipping shoreline features beach berms that may look like faults in the volume curvature. Further, the 3D data contains footprints. A major fault can be seen near the center of the image below (Figure 3).

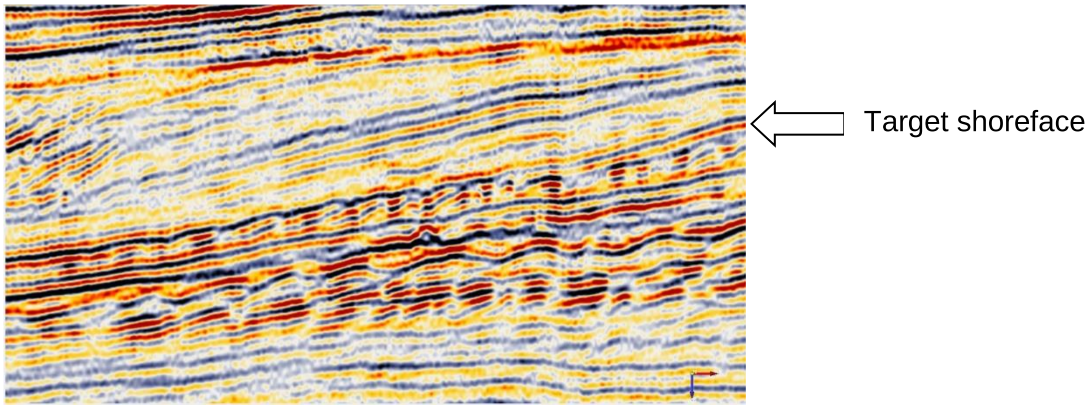

Figure 2 In-line through the F3 showing the west facing depositional trends

The following figures show the results of the most positive curvature attribute over a horizon slice 20 ms below the top-set horizon picked on the 3D seismic data. At smaller step-outs, one can see many strandplains whereas with a larger aperture only few big one are visible.

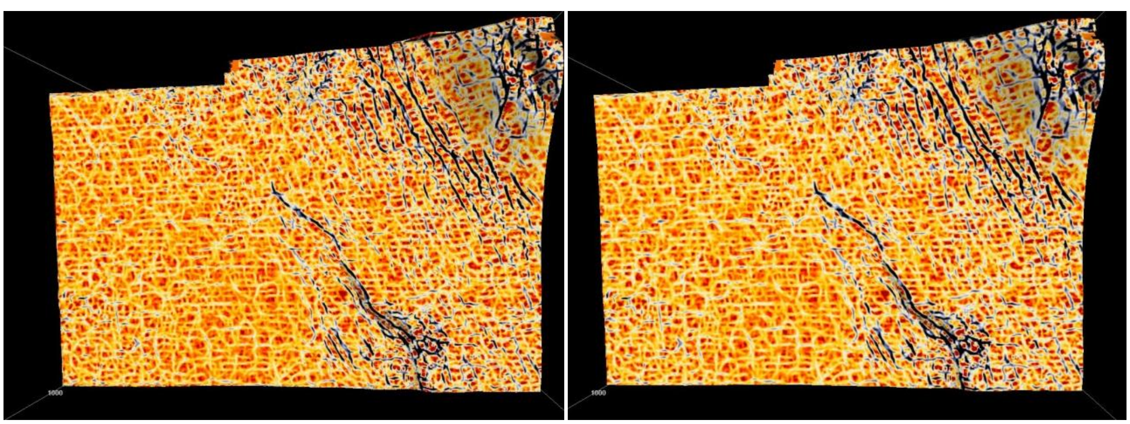

Figure 3 Most Positive curvature step-out 2 (left) and step-out 3 (right)

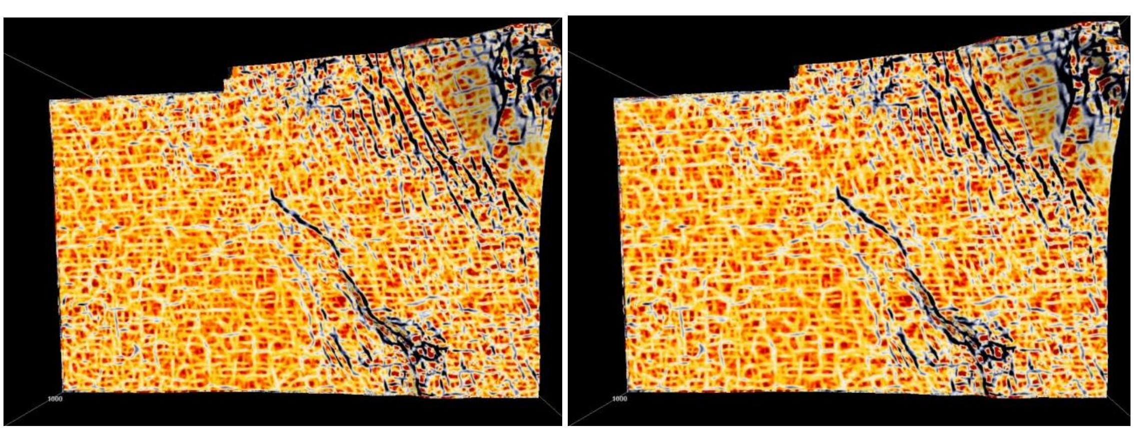

Figure 4 Most Positive curvature step-out 4 (left) and step-out 5 (right)

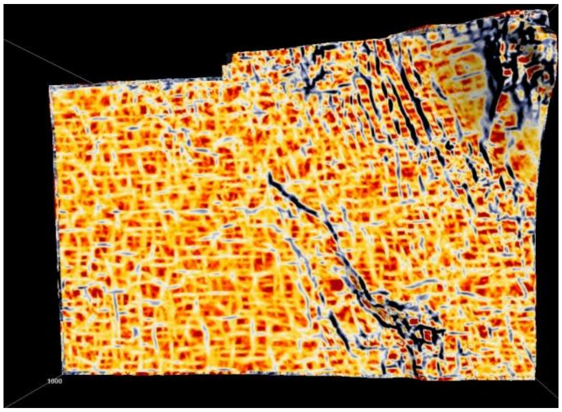

Figure 5 Most Positive curvature step-out 7

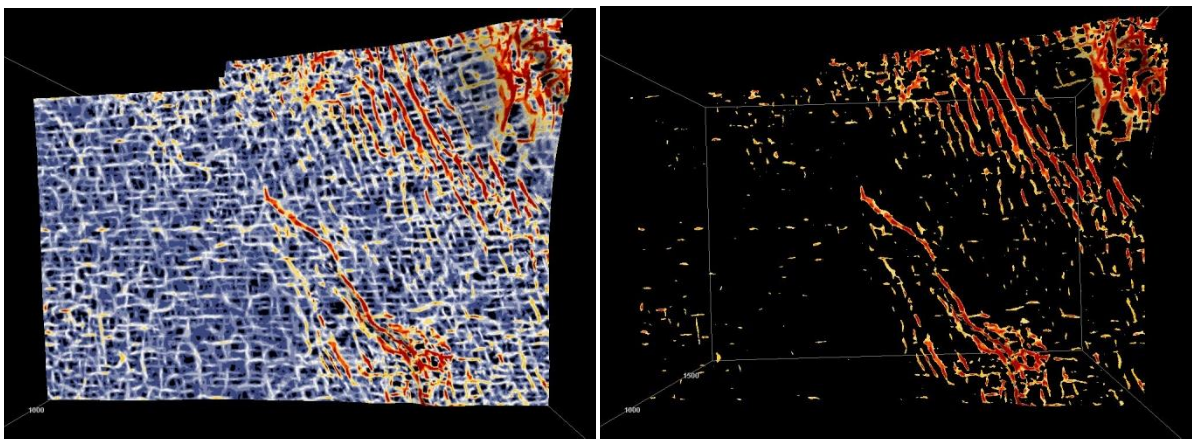

Figure 6 Display of neural network display using most positive curvature attributes step-out 2, 3, 4, 5, and 7.

The classification volume has the advantage that it may be switched on or off for any given class for a specific range of probabilities thus making it a robust interpretation tool in a visualization environment.

Conclusions

The neural network approach provides a robust way of analyzing data to improve prediction and create classifications. With the focus on unconventional exploration a subtle difference in an attribute not visible to the eye could make a huge difference. The most positive classified curvature cube provides a fast way to separate the lineaments at various apertures.

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