Factorial Kriging Analysis - a geostatistical approach to improve reservoir characterization with seismic data.

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ABSTRACT

In this work the Factorial Kriging analysis for the filtering of seismic attributes applied to reservoir characterization is considered. Factorial Kriging works in the spatial domain in a similar way to the Spectral Analysis in the frequency domain. The incorporation of filtered attributes as a secondary variable in kriging system is discussed. Results prove that Factorial Kriging is an efficient technique for the filtering of seismic attributes images, of which geologic features are enhanced. The attribute filtering improves the correlation between the attributes and the well data and the estimates of the reservoir properties. The differences between the estimates obtained by External Drift Kriging and Collocated Cokriging are also reduced.

INTRODUCTION

The integration of well data and seismic attributes using geostatistics has, nowadays, become more popular. Due to the limitations imposed by the seismic resolution, the reservoir mean proprieties are not correlated to seismic attribute volume, but to seismic attribute mean maps. It is well known, however, that, even after seismic processing, noises and sign distortions remain if not introduced by the processing itself. Moreover, inconsistency in horizons picking, during interpretation, worsens the quality of the obtained attributes with corresponding impact for its use as a predictive variable for reservoir mean properties estimation. It is also worth mentioning that monoattribute or mean maps may disguise the image of geologic features of different dimensions, hard to distinguish through conventional filtering techniques.

Factorial kriging works in the spatial domain in a similar way to the spectral analysis in the frequency domain. Events which can not be distinguished in the Fourier transformed domain may be separated in a variographic analysis and filtered by factorial kriging.

Seismic attributes, contrary to well data, are densily sampled, and its integration in kriging systems enhance the interwell estimations. The decisions about the seismic attribute feasibility is, in general, based in the correlation analysis between the attribute and the well data. Good correlations allow the attribute use. Nevertheless, applications to improve the attribute quality are not tried.

The general theory of Factorial Kriging Analysis has been developed by Matheron (1982) and has been used in different areas such as soil sciences, hydrogeology, geophysics, petroleum prospecting, etc... to distinguish local structures from the background. Factorial Kriging Analysis was first used in geophysics by Galli, Gerdil-Neuillet & Dadou (1984), as a technique for magnetic anomalies separation. Yao, Mukerji, Journel & Mavko (1998) used factorial kriging analysis to filter out the seismic small scale structure which is unrelated with porosity. The filtered seismic data was used for porosity estimation.

FKA relies on the assumption that a regionalized phenomenon can be seen as a linear sum of varied independent, zero mean subphenomena acting at different scales, each of which presents its own variogram or covariance model which will, linearly summed up, compound the variogram or covariance model of the regionalized phenomenon. The components are separated by kriging. The factorial kriging system is similar to an ordinary kriging system except by the sum of weights which must be null so that the mean of the components be null as well, and the cross covariance between the data and the estimated point consider only the covariance associated to the component to be estimated, For a more detailed presentation of factorial kriging, refer to Wackernagel(1995).

In this paper we show a case study in the upper interval of an offshore canalized turbidite reservoir in Campos Basin, Brazil. FKA was applied to an acoustic impedance (Imp) image obtained from a seismic stratigraphic inversion. The field area presents 45 wells. The estimation obtained by ordinary kriging – Figure 1 – is a good approximation to the field reality. Other estimations presented here consider the field first 11 wells so that its results may be validated against the estimation obtained with the complete dataset.

In this paper, we only present results obtained with the acoustic impedance for the upper interval of the reservoir. Mundim (1999) brings results obtained through the FKA for other attributes extending it to the other intervals of the reservoir under discussion.

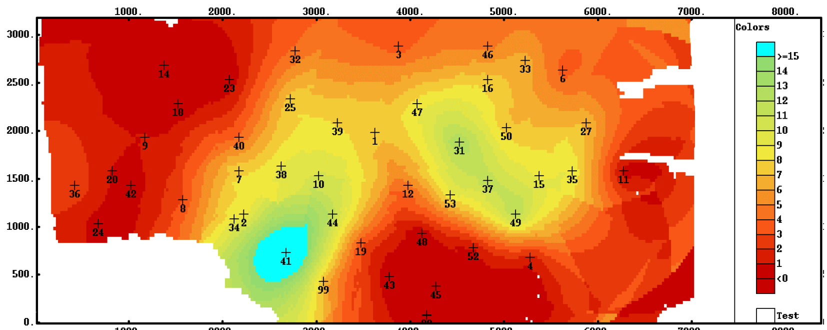

Figure 1: $H\phi$ ordinary kriging estimation with the complete dataset (45 wells)

IMPROVING THE SEISMIC ATTRIBUTE IMAGE BY FACTORIAL KRIGING

The acoustic impedance image from the considered interval is showed in Figure-2. We can observe a noise aligned in the

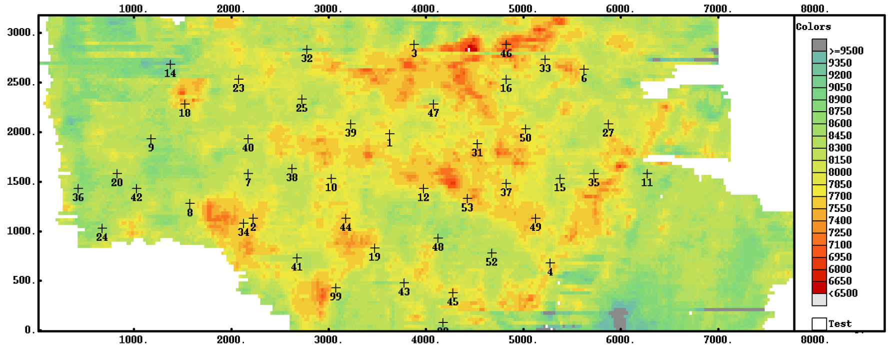

Figure 2: Original acoustic impedance image from the upper reservoir interval

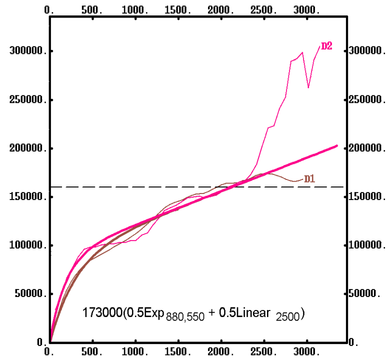

Figure 3: Acoustic Impedance experimental variogram and the nested corregionalization model fitted.

direction E-W and a braided pattern affecting the data. A nested variogram with two structures - an exponential one and a linear one – each of which representing 50% of the image variance was fitted – Figure 3. The short range structure (the exponential one) is correlated to noises which disguise the attribute image, the long range structure is correlated to the geological features, such that it is possible to calculate a signal/noise ratio as being the variance relation between the long range structure divided by the short range one, which gives us 1 for the image under discussion.

The data observed drift was well fitted for lenghts limited to 2500 m ranges.

Figure 2 image was filtered, which means that the short range structure, which was correlated to noises, was rejected by Factorial Kriging, resulting in the image in Figure 4. It is observable that the E-W aligned noises as well as the braided pattern were drastically attenuated. The lowest values of the acoustic impedance, which are correlated to Hϕ, in this field, allows the filtered image to clearly show a canalized body running SW-NE with an inflection W-E in the core area. A comparison between before and after impedance filtering images with the Hϕ map – Figure 1 –shows that the filtered image better reflects the field geological reality.

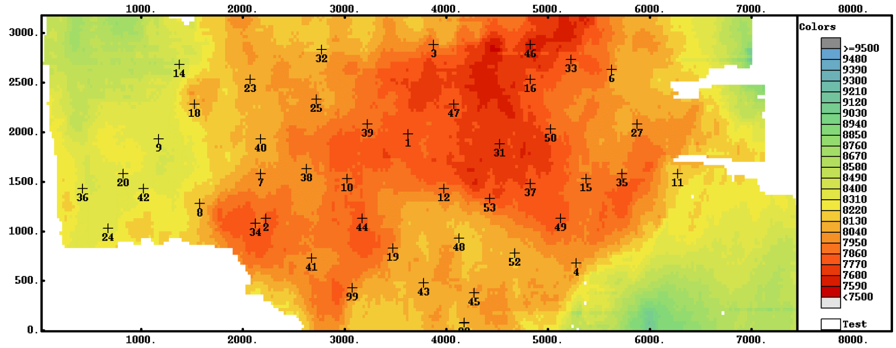

Figure 4: Filtered acoustic impedance image

FILTERED ATTRIBUTE USE FOR H• • ESTIMATION

As seen above, filtering improves the attribute image quality. Such improvement, however, doesnot warant its use as a predictive variable for the Hϕ in kriging systems. Notwithstanding, the correlation coefficient between Hϕ and impedance (based on the 45 wells) was improved from -35% to -80% after filtering. The Hϕ estimation for the 11 wells dataset by collocated cokriging using the pre-filtered Imp with collocated variable is presented in Figure 5. Such map shows the impedance aligned E-W noise. Besides that, one may see that the east part of the field was not well estimated (compare to Figure 1). On the other hand, the estimation obtained with the filtered attribute as collocated variable – Figure 6 – doesnot show

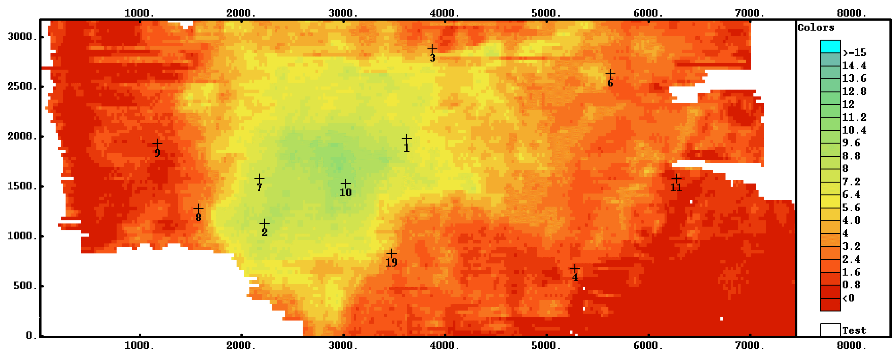

Figure 5: Hϕ maps estimated by collocated cokriging with original acoustic impedance and the 11 wells dataset..

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the aligned noises, the east part of the field is better estimated and the sand area of the reservoir is more clearly delimited.

The above estimations were obtained by Collocated cokriging, although they could be calculated by external drift kriging. Which one is the best technique? It depends on the correlation model between the well data and the seismic attributes. In the petroleum prospecting, such question is a hard one due to the small number of well data usually available, raising difficulties for the building up of trustful models of spatial correlation between the attributes and the well data. Nevertheless, an assertion can be made – the two techniques do not present the same results.

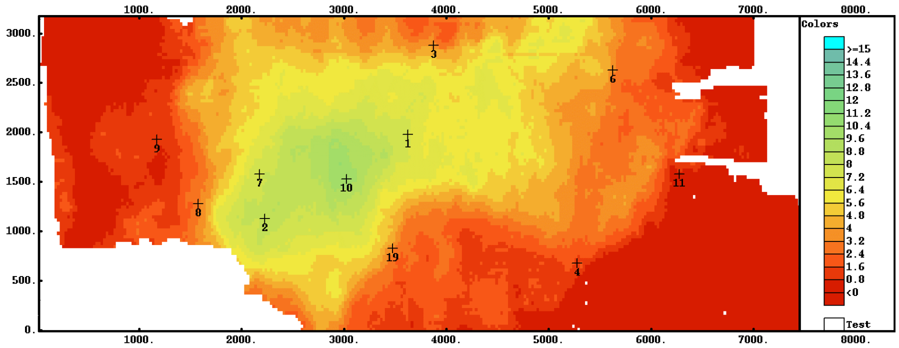

Figure 6: Hϕ maps estimated by collocated cokriging with the filtered acoustic impedance and the 11 wells dataset

The use of noisy secondary variables seems to enhance the differences between the two techniques. Figure 7 shows the differences histogram, pixel by pixel, between the Hϕ estimations obtained by external drift kriging and collocated cokriging using pre-filtered impedance. Figure 8 was obtained using filtered impedance. Both distributions present almost zero mean. However, the variance for the first one was higher. Our assumption is that the filtered attribute reduces the differences between the estimations significantly, minimizing the effect of the chosen technique in the estimation significantly,minimizing the effect of the the chosen techinique in the estimation.

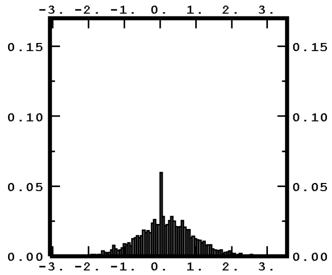

Figure 7: Histogram from the differences pixel by pixel between the external drift kriging estimation and the collocated cokriging estimation with the original acoustic impedance how secondary variable.

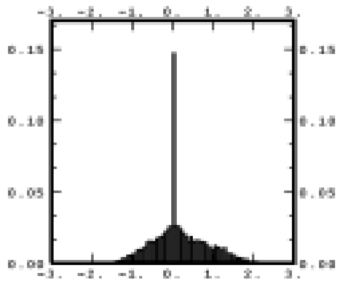

Figure 8: Histogram from the differences pixel by pixel between the external drift kriging estimation and the collocated cokriging estimation with the filtered acoustic impedance how variable.

CONCLUSIONS

Factorial Kriging Analysis proves itself an efficient tool for seismic attributes images noise removing. The image of the filtered attribute gains definition and geological significance. The correlation coefficient between the attributes and the Hf well data is also improved. The use of filtered attributes in collocated cokriging systems offers a better definition of the reservoir morphology. It was also shown that the use of Factorial Kriging to filtered seismic attributes reduces the difference between the estimation obtained through external drift kriging and collocated cokriging.

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