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Application of à trous DWT in the detection of seismic thin layers

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Extended Abstract

Summary

In hydrocarbon exploration, detecting thin layers is one of the most important parts of geophysical interpretation. Seismic data received from horizons whose distances are less than the transmitted wavelength interferes in the sections will represent a single layer. It is possible to use à trous DWT domain to detect thin layers in seismic data acquired from oilfields at the first high-pass scale. In this paper, the use of instantaneous attributes in the à trous DWT domain to detect thin layers is investigated. The data is decomposed by 1-D à trous DWT. In this way, the events are filtered out and, the values matched by the mother wavelet are calculated at each scale. Once the decomposition step is applied, at high scales, the events in higher frequencies remain, and this can be a significant aid in the detection of thin layers. The results of this step indicate that applying this method to synthetic and real data can have a significant improvement in the separation of events from each other. Conventional seismic attributes have also been used to highlight the results in real data.

Introduction

Spectral analysis is an effective method for seismic signal analysis in oil exploration. This method decomposes the seismic signal into a discrete number of signal subsets, each corresponding to the amplitude and phase for a narrow frequency band .These narrow bands represent the power of seismic reflection at characteristic frequencies for different horizons. Spectral analysis is used in direct detection of hydrocarbons, seismic damping analysis, channel identification, and thin layer thickness estimation. Recently, however, efforts have been made in improving the resolution of spectral analysis algorithms. Heisenberg's uncertainty principle shows that there is always a limit to the possibility of improving time and frequency resolution simultaneously. Wavelet transform is a relatively new conversion, but some of the ideas in this method have a very long history. With the introduction of the wavelet transform, new doors were opened for signal analysis. The ability to display signals at different resolutions is one of the most important wavelet transform capabilities. Wavelet transform has many applications in various sciences. The main applications of this method generally include detecting discontinuity points, identifying the net frequency of the signal, removing noise from the signal, and so on.

Methodology and results

Since thin layers are the passage or the accumulation place of hydrocarbons, it is important to identify them. However, the identification of thin layers in seismic reflection sections is not well detectable, thus, we use different methods to detect thin layers. The à trous DWT may be a suitable tool to apply on instantaneous wavefield attributes. Therefore, thin layer detection using the à trous DWT was investigated in this paper.

Assuming that the scale function and the wavelet ($\phi,\psi,\hat{\Phi},\hat{\Psi}$) are designed by the filter ($h, g, \hat{h}, \hat{g}$), UDWT can efficiently decompose the input signal f_0 into $\{\beta_1, \cdots, \beta_J, f_J\}$ through the following algorithm (Shensa, 1992), where β_j ($j \in \{1, 2, \cdots, J\}$) represents the wavelet coefficients on the scale j, and f_J represents the wavelet coefficients on the coarsest resolution (Wang et al, 2019):

$$\begin{cases} f_{j+1}[m] = \left(\bar{h}^{(j)} * f_j\right)[m] = \sum_n h[n] f_j[m + 2^j n] \\ \beta_{j+1}[m] = \left(\bar{g}^{(j)} * f_j\right)[m] = \sum_n g[n] f_j[m + 2^j n] \end{cases} \quad (1)$$

$$f_i[l] = \left(\hat{h}^{(j)} * f_{i+1}\right)[m] + \left(\hat{g}^{(j)} * \beta_{i+1}\right)[m] \quad (2)$$

Applying this method to synthetic and real seismic data demonstrates the efficiency of spectral analysis of this particular transformation. As the first transient scale can provide important information about thin layers, one of the most important shortcomings of this method is how to choose the right wavelet for the results. Hence, we looked at two types of wavelets having different lengths. Since the results are analyzed in the wavelet domain and the inverse wavelet process is not applied, shorter wavelengths can also be used.

Results and Conclusions

The use of instantaneous attributes in the à trous DWT domain was investigated to detect thin layers in seismic data. Decomposition of the data was made by using 1-D à trous DWT to filter out the events at high scales, and ultimately, to detect thin layers. This method was applied on both synthetic and real seismic data. The results indicated a significant improvement in the separation of events from each other. Thus, the à trous DWT can be suggested as an appropriate method for the detection of seismic thin layers.