Highlighting Oil and Gas Reservoirs in Seismic Signals with the W Transform

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Abstract

Time-frequency analysis (TFA) is a crucial tool to identify local features in nonstationary signals. When applied to seismic data, it can help reveal subsurface structures and properties of the geologic models. In particular, the presence of oil and gas reservoirs can be inferred from the appearance of low-frequency anomalies in the time-frequency spectrum. Therefore, due to their robustness against high-frequency energy attenuation, TFA methods seem to be an interesting tool for detecting and monitoring gas-saturated reservoirs. Standard TFA methods convolve the signal with a window function to more clearly visualize spectrum variation. In this regard, the choice of the window function is fundamental in spectral characterization and leads to diverse time-frequency transforms. The Gabor transform, for example, employs a fixed-length sliding window, resulting in a different number of oscillations according to the frequency. This leads to a lower time resolution at high frequencies compared to low frequencies. In contrast, the S transform (ST) employs a frequency-dependent time window that fixes the number of cycles. The continuous wavelet transform exhibits similar frequency-dependent behavior of the ST. For this reason, ST's relatively poor time resolution of low-frequency events may obfuscate the aforementioned geological anomalies. The recently proposed W transform (WT) mitigates this limitation by incorporating the instantaneous frequency of the signal (estimated with the Hilbert transform) in the window function of the ST. This modification concentrates the energy of the signal around its dominant frequencies and thus highlights the high- and low-frequency bands contained in seismic spectrograms. By its turn, the energy concentration in the time-frequency spectrum can be enhanced by using the scaling and trend parameters that define the WT. We use the Marmousi model as a case study to compare the ST with the WT. To conclude, this study tries to enhance reservoir identification and monitoring during production, by using the WT. Moreover, the attributes of the WT can produce valuable attributes to feed a Machine Learning inspired time-lapse inversion strategy. Besides, we have also investigated the role of two tunable parameters presented in the WT in the context of information theory by minimizing the Rényi entropy.