Improving 3D seismic data resolution by using local phase transformation coupled with the quaternion representation

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Resumo: Seismic data often lacks sufficient resolution required to distinguish reflected events clearly. Various methods based on the wavelet-reflectivity convolutional model have been developed in the last 50 years. A new approach based on the complex seismic trace and the transformation of its instantaneous phase was proposed by Porsani, 2022, and Porsani and Ursin, 2024, allowing for sharpening the reflections at local maxima or minima. The reflectivity model under consideration presumes that between two neighboring reflections, there is an elementary seismic layer. Here, for 3D seismic data, we apply the Hilbert transform also to the in-line and cross-line direction, expanding the non-linear phase transformation method to the 3D case via quaternion representation, resulting in new components with improved temporal and spatial resolution. Numerical results of 3D seismic data from the Marlin field and the OpendTect repository illustrate the performance of the new approach.

In seismic oil exploration, particularly in the study of reservoirs, deconvolution is an important step of seismic processing, applied to improve the temporal resolution of traces, allowing better top and bottom identification of thinner layers and thus better definition of subsurface geology. When used for this purpose, it is called wavelet or spiking deconvolution (Treitel and Robinson, 1966; Ulrych et al, 1995). Wavelet spiking deconvolution is a popular method for improving seismic resolution. The assumptions are that the reflectivity series has the characteristics of white noise and that the seismic wavelet is minimum-delay. When these assumptions are not fulfilled an improved result can be obtained by using a pulse-shaping filter assuming an estimate of the wavelet is known. Here we use a completely different approach by considering the analytic signal or complex trace (Taner et al, 1979) which is characterized by an instantaneous amplitude and phase. The instantaneous phase is changed with a non-linear function given a new signal with the same instantaneous amplitude but a modified phase function. The process enhances positive peaks in the input signal and spreads out the negative parts. n this paper we extend the Porsani and Ursin (2024) approach to increase the temporal and spatial resolution of the 3D seismic data, which is based on a non-linear transformation of the local phase of the quaternion representation of the data volume.

In this paper, we extend the Porsani and Ursin (2024) approach to increase the temporal and spatial resolution of the 3D seismic data, which is based on a non-linear transformation of the local phase of the quaternion representation of the data volume.

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