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Seismic wave characterization using complex trace analysis in the stationary wavelet packet domain

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ABSTRACT

One of the most important tasks in seismology and applied geophysics is the identification of the different kinds of waves that form a seismic record by means of polarization analysis. In particular, this involves the extraction of body waves (linear polarization) or surface waves (mostly elliptical polarization) from a set of seismic data and which forms a key point in several studies.

In this work, a new method of time–frequency polarization analysis based on the stationary wavelet packet transform is developed. The proposed approach identifies and extracts automatically the different waves included in the signal, dependent on the reciprocal ellipticity. Moreover, the algorithm provides enough information to the user to allow them to also manually select the reciprocal ellipticity intervals, and then extract the corresponding waves of interest contained in the signals.

The proposed polarization estimation method and the automatic features extraction algorithm have been evaluated first using synthetic signals, and then applied to real seismic records. Based on the results obtained from both synthetic and real signals, we can conclude that the proposed method correctly identifies and extracts automatically the linearly and elliptically polarized waves from the signal, discerning clearly both types of polarization. Moreover, the proposed method is able to identify and extract signals with different kinds of elliptical polarization, allowing us to understand better the characteristics of the Rayleigh waves.

1. Introduction

One of the most important tasks in seismology and applied geophysics is the identification and extraction of the different types of waves that form a seismic record by means of polarization analysis. This involves the extraction of body waves (linear polarization) or surface waves (mostly elliptical polarization) from a set of seismic data.

Rayleigh waves are dispersive when they propagate along a vertically heterogeneous medium. Due to the subsoil structure, their velocity and polarization properties have a high dependence on the frequency and the mode of propagation [1]. The estimation of the frequency-dependent velocities (dispersion curves) is therefore a crucial point when conducting site effect assessments by ambient vibrations [2–5].

Vidale [6], René et al. [7] and Li and Crampin [8] proposed different time-domain methods based on complex trace analysis (CTA) and defined the instantaneous polarization attributes for the Rayleigh and shear-wave identification. These methods analyze only the vertical and radial components. Morozov and Smithson [9] proposed a variational method, which allows the generalization to any number of components and therefore the identification of Love waves.

The CTA method analyzes seismic data as analytic signals, which enables the local characteristics of the signal to be maintained, providing the instantaneous amplitude and phase. The concept of the complex analytic signal was first introduced by Gabor [10] for the study of the minimum bandwidth needed for the transmission of radio and television signals. In seismology, Farnbach [11] applied CTA analysis to estimating the enveloped and the instantaneous phase of the seismic records and subsequently the arrival time of the different seismic waves. Taner and Sheriff [12] and Taner et al. [13] also applied CTA analysis to single-component seismic data and defined the concepts of reflection strength and reflection polarity as the instantaneous amplitude and the sign of the instantaneous phase, respectively. René et al. [7] defined the complex multicomponent signal, with the real orthogonal components that correspond to the registered components, and the imaginary components, obtained by

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