Denoising 3C microseismic data using a simple thresholdless polarization filter

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Abstract

Microseismic data is essential in the field of exploration geophysics, providing researchers with useful information about a variety of subsurface-related operations such as hydraulic fracturing and monitoring. Microseismic datasets often have a low to moderate signal-to-noise (S/N) ratio, making data processing and interpretation not only difficult, but also uncertain and imprecise. There are various ways for reducing noise and increasing the S/N ratio of 3C data, ranging from simple bandpass filtering to more complex strategies like time-frequency and τ-p filtering. Polarization filtering (PF) methods and algorithms, on the other hand, are based on the assumption that the acquired data has particular polarisation features. One such assumption, which is the key to most PF approaches, is that pure body waves (i.e. P- and S-wave arrivals) may usually be considered to be linearly polarised. Most PF strategies in this context focus on determining a specific function that is applied to the data to enhance polarised signals and attenuate non-polarized data (i.e. random and other types of noises). This function is typically computed for a sliding window along the time axis within which a specific waveform relationship (e.g. rectilinarity) is calculated in such a way that the resulting function takes a large value (close or equal to 1) when the phase arrivals are linearly polarised, but a low value (close to zero) when they are not. Furthermore, most approaches employ different thresholdings to improve the differentiation between polarised and non-polarized data. The thresholding is especially important because if it is not set correctly, the onset and/or overall phase waveforms may be altered beyond what is reasonable. The proposed approach minimises these undesirable waveform deformations because no thresholding is necessary to considerably denoise the data. Denoising is accomplished essentially by first rotating the 3C data until the majority of its energy is forced to lie in one component and then deleting the remaining "signal" (noise) that is present in the other two. Finally, the data is de-rotated in order to return to its original orientation. It can be demonstrated that this is equivalent to utilising a traditional eigenvalue-eigenvector approach (e.g., SVD-based), albeit considerably more intuitive and user-friendly. It is also more computationally efficient because no eigenvalues or eigenvectors are required, and the polarisation angles are derived using simple closed-form formulas. Furthermore, in contrast to the conventional techniques, the rotation-based strategy allows for a more generic formulation: instead of minimising (or maximising) the energy, which presupposes Gaussian noise, one may choose another norm specifically designed to deal with non-gaussian noises. In this regard, we investigate the usage of the Lp-norm, with p in [1,2), to include robustness in the presence of outliers. The algorithm's usefulness in improving the S/N ratio of noisy 3C data is demonstrated by means of synthetic and field data examples.