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Seismic Event Characterization using Manifold Learning Methods

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Manifold learning is a branch of machine learning that focuses on compactly representing complex data-sets based on their fundamental intrinsic parameters. One such method is diffusion maps, which reduces the dimension of the data while preserving its geometric structure. In this work, diffusion maps are applied to several seismic event characterization tasks. The first task is automatic earthquake-explosion discrimination, which is an essential component of nuclear test monitoring. We also use this technique to automatically identify mine explosions and aftershocks following large earthquakes. Identification of such events helps to lighten the analysts' burden and allow for timely production of reviewed seismic bulletins.

The proposed methods begin with a pre-processing stage in which a time–frequency representation is extracted from each seismogram while capturing common properties of seismic events and overcoming magnitude differences. Then, diffusion maps are used in order to construct a low-dimensional model of the original data. In this new low-dimensional space, classification analysis is carried out.

The algorithm's discrimination performance is demonstrated on several seismic data sets. For instance, using the seismograms from EIL station, we identify arrivals that were caused by explosions at the nearby Eshidiya mine in Jordan. The model provides a visualization of the data, organized by its intrinsic factors. Thus, along with the discrimination results, we provide a compact organization of the data that characterizes the activity patterns in the mine.

Our results demonstrate the potential and strength of the manifold learning based approach, which may be suitable to other in other geophysics domains.