Analysis of Seismic Time Series Data via Statistical Tests and Imaging Techniques

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Abstract

Distributed Acoustic Sensing (DAS) has emerged as a powerful tool for monitoring geophysical hazards such as earthquakes. In this study, we propose a systematic framework for analyzing time-series DAS data recorded along an optical fiber installed beneath a coastal highway on the east coast of Taiwan, capturing seismic signals at millisecond resolution. Through algebraic transformations and visualization techniques, the raw DAS signals are first converted into image representations. Unlike conventional U-Net-based approaches, we develop a uniform segmentation strategy and further extend it to a non-uniform scheme to identify candidate partition times corresponding to seismic phase arrivals. To determine whether a detected partition corresponds to a true P-wave arrival or a spurious detection, we theoretically derive a statistical hypothesis test for distinguishing between two time series or functional data objects. Extensive simulation studies and comparisons with existing methods demonstrate that the proposed approach consistently outperforms competing techniques from seismic analysis, machine learning, and deep learning. Potential applications to seismic early warning systems are also discussed.

Keywords: Seismic Data Analysis, Distributed Acoustic Sensing (DAS), P-Wave Detection, Uniform Segmentation, Hypothesis Test.