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Graph Neural Networks for Spatio-Temporal Seismic Event Localization and Characterization with Multimodal Integration

Research on Graph Neural Networks (GNNs) has advanced rapidly, with recent architectures successfully applied to seismological tasks such as earthquake source characterization and event association. Inspired by advancements in traffic forecasting and temporal knowledge graph completion, we propose dynamic GNNs that integrate graph convolutional layers and autoencoders to capture spatio-temporal correlations in seismic fields. Our approach is trained on thousands of earthquake events recorded by seismic networks in California (SCSN) and France (RSN), enabling the model to learn key properties of the seismic field. Unlike traditional Graph Convolutional Networks, our method dynamically updates the graph structure, allowing it to accommodate seismic networks of arbitrary size and time-varying configurations. The trained model achieves a root-mean-square error (RMSE) of less than 0.1 when predicting earthquake magnitudes, using either broadband or narrowband signals, demonstrating strong robustness for real-time characterization. Additionally, the location accuracy scales with a characteristic length derived from the clustering properties of the network, achieving an RMSE of typically less than 10 km for the SCSN. Finally, we demonstrate how large language models (LLMs) can be integrated with GNNs to incorporate additional textual descriptions from bulletins, reports, and historical data, complementing the graph-based features extracted by GNNs.

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