Team 003

A GNN-based Interactive Application for Earthquake Early Warning

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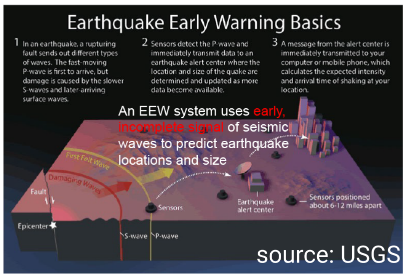
Motivation/Introduction



Earthquake **e**arly **w**arning systems are life-saving systems for high-risk areas.

Deep learning based methods may provide more robust predictions than conventional methods, yet the usefulness hasn't been proved.

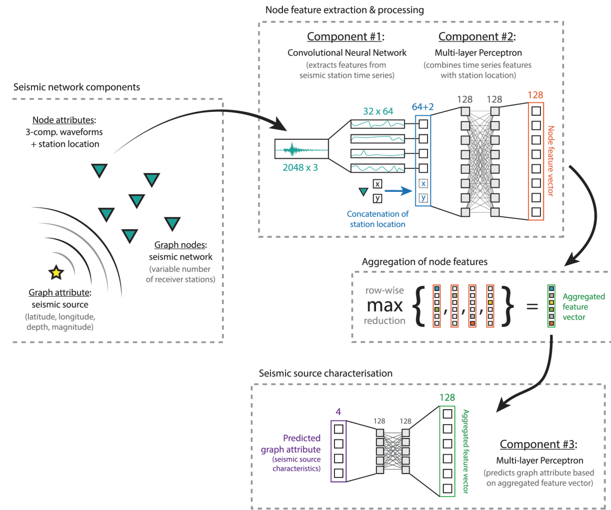
Approach

Four building blocks: Data scraping, GNN modeling, Data storage, and Interactive dashboard building

GNNs can better process non-Euclidean structures (i.e. seismic networks distributed irregularly spatially)

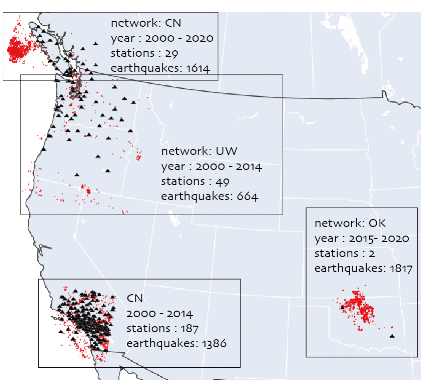
We have trained new GNN models for other high seismic risk areas, where this type of model did not exist to the best of our knowledge.

Experiments were conducted by randomly dropping 10%-40% of stations before inference.



Sourced from "van den Ende, M. P. A., & Ampuero, J.-P. (2020). Automated seismic source characterization using deep graph neural networks. Geophysical Research Letters, 47, e2020GL088690.

Data



Study period: 2000 - 2020
Data downloaded from the IRIS data center via Obspy API

# of stations : 266, # of earthquakes: 5481
data size ~5 Gb

Experiments

Performance was quantified for each experiment using mean +/- std of MAE error, over 20 samples from the modeled distribution.

GNN inference is relatively efficient and robust to varying station response levels, making it more suitable for real-time prediction compared to other DL methods.

Region	Location Error (km)	Depth Error (km)	Magnitude Error (Richter)
California	25.24 +/- 22.61	3.38 +/- 2.93	0.15 +/- 0.16
Pacific Northwest	68.66 +/- 99.97	3.51 +/- 6.03	0.14 +/- 0.15
Oklahoma	40.88 +/- 33.12	1.57 +/- 1.47	0.22 +/- 0.19
Vancouver Island	54.77 +/- 51.55	1.59 +/- 4.95	0.22 +/- 0.22

Database

mongoDB

3 collections

We integrated MongoDB with Flask-PyMongo to build our web application.

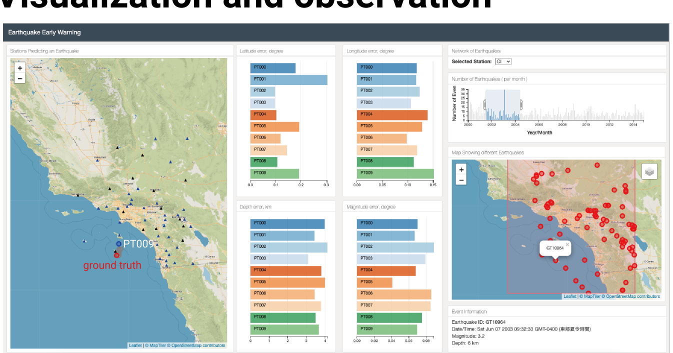
Earthquake id	Experiment id	Stations	Event latitude/ latitude error/ latitude standard deviation	Event longitude/ longitude error/ Longitude standard deviation	Event magnitude/ magnitude error/ Magnitude standard deviation
String	String	Array	Double	Double	Double

Earthquake id	Stations	Event latitude	Event longitude	Event magnitude	Event time	Network
String	Array	Double	Double	Double	Date	String

Station id	Station name	Station latitude	Station longitude	Network
Int	String	Double	Double	String

Flask

Visualization and observation



Previous GNN studies observed that the total number of stations affects the quality of predictions.

We observed that the closest station to the earthquake source also plays a critical role in constraining the source location, with lesser impact on the magnitude and depth predictions.

Summary

We explored the possibility of using a GNN based method for earthquake early warning systems.

The experiments were done on high-seismic risk areas: Southern California, Pacific NW, Vancouver Island, and Oklahoma.

We organized the experiment results into three NOSQL databases using MongoDB.

We created an interactive dashboard to visualize the deviations between the predicted attributes and the ground truth.

We discovered that the closest station plays a key role in constraining source locations, with less importance for magnitude and depth.

The GNN model is suitable for real-time deployment though prediction uncertainties are high and model improvement is needed.