Data-Driven Earthquake Location Method

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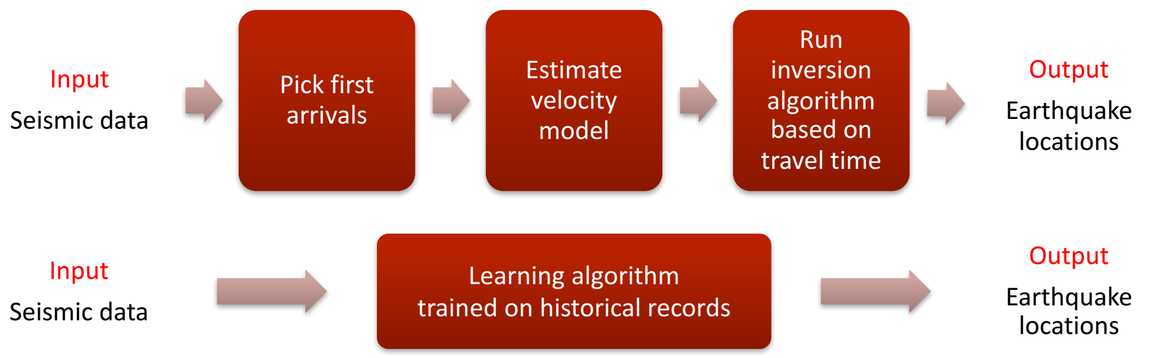
ABSTRACT

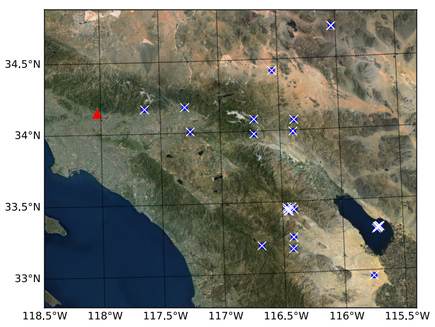
Earthquake location is one of the most fundamental and important problems in Geophysics. It could provide valuable information for rescue guidance, hazard assessment and scientific study of the Earth's inner structures. In this project, we have tried to apply machine learning algorithms trained on historical seismic wave records to locate earthquakes which only needs one or few stations and does not rely on first arrival picks and velocity model.

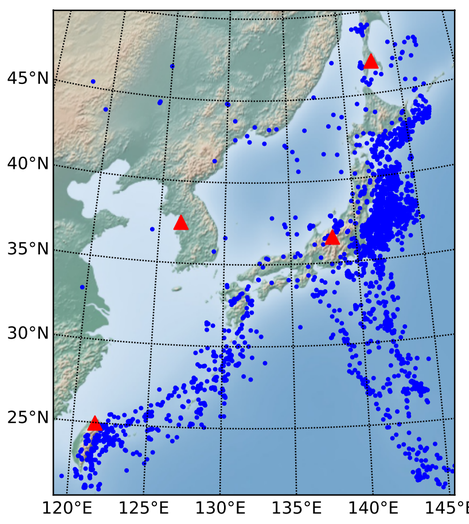


DATA

Two data sets are being tested now: one covers locally small region in California where has only 30 small earthquakes; the other one covers large region around Japan where large earthquakes happened (2510 above Mw 5).

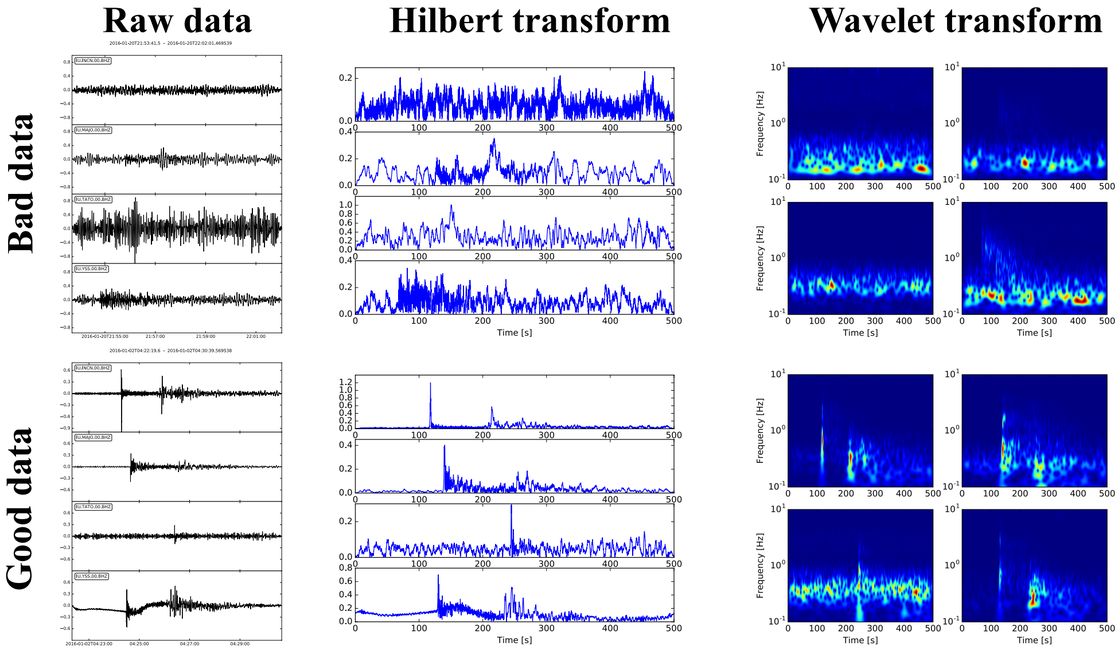
Dataset in CA





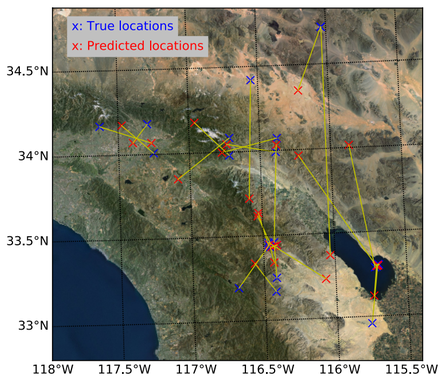
Dataset in Japan

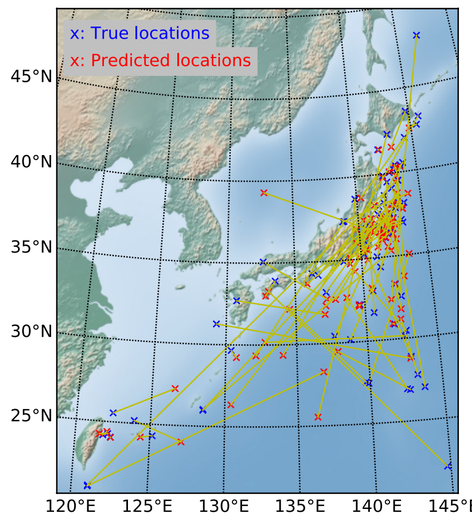
Raw data | **Hilbert transform** | **Wavelet transform**



K-NEAREST NEIGHBORS

Result in CA



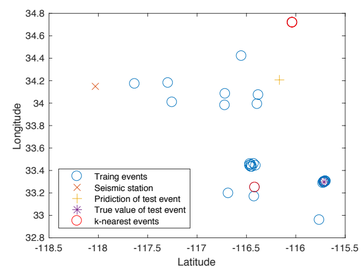


Result in Japan

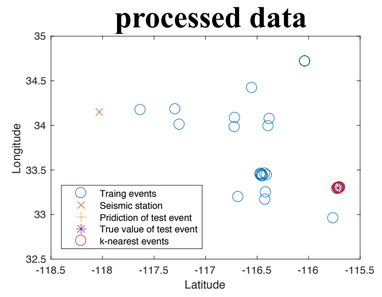
We calculated the weighted average of the *k*-nearest neighbors, weighted by the inverse of their distance. First we tried to run a quick-and-dirty k-NN regression on raw data to get a main idea and then tried to improve our algorithm step by step.

Mean error:	evlo	evla
Train on raw data (CA)	0.4066	0.5250
Data processing (CA)	0.2201	0.3822
Different distance function (CA)	0.1351	0.2654
Choosing parameter k (CA)	0.1371	0.2396
Three-components Data (CA)	0.4177	0.3313
CA data location limit	0.0342	0.0530
More events (Japan)	2.8803	2.9646
Four stations (Japan)	2.9505	3.8858
Japan data location limit	0.0601	0.0623

Result of raw data



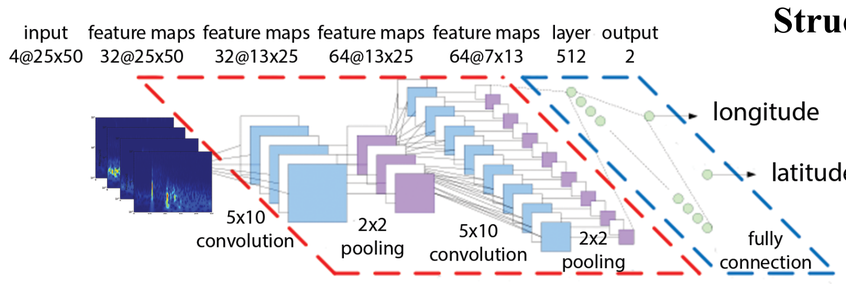
Result of processed data



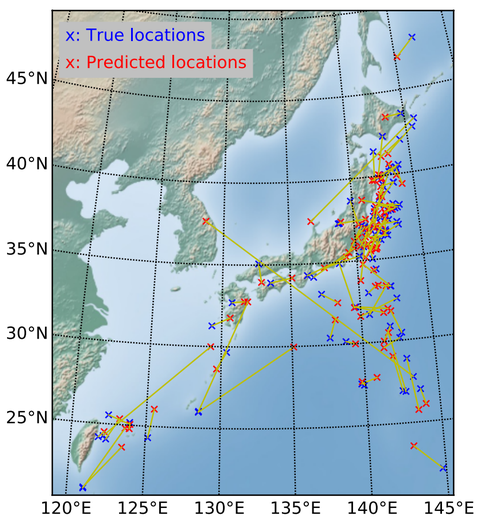
CONVOLUTIONAL NEURAL NETWORKS

We have built a convolutional neural network and trained it using 2510 earthquakes around Japan. The structure of the CNN is shown below. The raw data, data after Hilbert transform and Wavelet transform are all used for training.

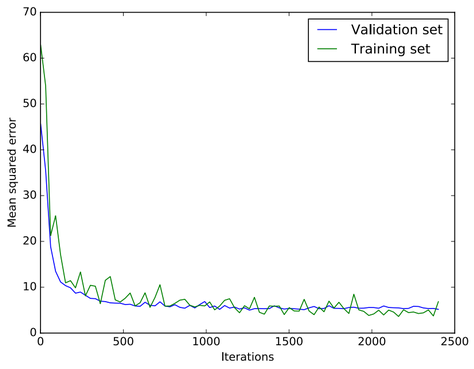
Structure of CNN

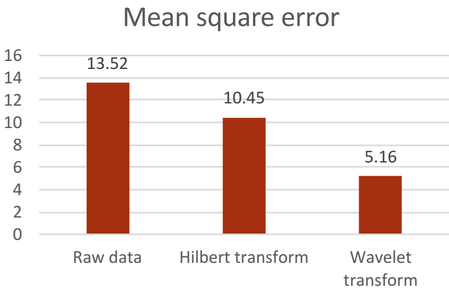


Result in Japan



Error vs. iterations





CONCLUSIONS

Both algorithms show reasonable results on earthquake locating. CNN has better accuracy while testing on the data in Japan. But currently the two algorithms could not provide as accurate results as traditional methods. Further improvements would be required to put them into practical application. Possible reasons for mislocating may include: 1. background noise 2. not enough historic data. 3. errors of finding nearest neighbor. 4. errors in down sampling of input data.

REFERENCES

Data sources: Incorporated Research Institutions for Seismology (IRIS) (www.iris.com), Southern California Earthquake Data Center (scedc.caltech.edu)

http://parse.ele.tue.nl/cluster/2/CNNArchitecture.jpg

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