Identifications of shallow slow earthquakes based on deep learning in the Nankai trough

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Introduction: Recent development of seismic and geodetic observations has brought us to find a new earthquake category as low-frequency earthquakes (LFEs). LFEs generally deplete radiated energy in higher frequencies, while rich in longer frequency components compared with ordinary earthquakes of similar size. LFEs show tremor-like waveforms continuing longer than several minutes. Investigations of the source processes of LFEs will help us to understand a diversity of earthquake generation processes and frictional properties along faults, especially for those located in subduction zones.
We have studied shallow LFEs that occurred off the Kii peninsula, observed by DONET ocean-floor observation network. Our studies have depended on visual inspections to detect LFEs because LFEs were not detected by the automatic event detection system of DONET because of the emergent onsets. In order to monitor LFE activities, it is necessary to develop automatic detection systems which also distinguish LFEs from ordinary earthquakes.
In this study, we introduce our ongoing project to develop an automatic detection system of LFE based on AI using machine learning approach. As described above, LFE signals are characterized by frequency contents and signal duration. Therefore, we use running spectrum images for the detections which can represent differences in the frequency contents as well as signal duration. Based on image recognitions of running spectrum, we try to detect and distinguish LFE signals from ordinary earthquakes and background noise.
Method: We use a deep convolution neural network (CNN) for the detections of LFE signals from continuous images of running spectrum. We use running spectrum images of DONET records, which are periodically created every hour for data quality control. Since low-frequency components from smaller LFEs are below noise level, we use plots of higher frequency components between 2-10 Hz. The spectrum image was converted to gray scale with its intensity proportional to logarithm of the signal power. Adjusting the image size suitable for the processing and connecting hourly plot, one day spectrum images were created.

Since CNN is a supervised machine learning approach, we prepared training datasets for LFEs, ordinary earthquakes, and background noise, from the continuous running spectrum images. The training image has 64x64 pixels, corresponding to signals of 2-10 Hz during 225 s time window. LFE training dataset were created from our LFE catalog created for the intensive activities in 2015 and 2016. A set of 16710 training images were created from 374 events. For ordinary earthquakes, training dataset were created based on a catalog from automatic DONET hypocenter determinations. A set of 27294 images were created from 771 events which occurred in January and February 2016. We also included 924 images at P-wave arrivals from 22 teleseismic events worldwide with magnitude 7 or larger. Noise images were created from randomly selected time windows of which occurrence times of LFEs, ordinary earthquakes, and teleseismic events were excluded based on the catalogs. A set of 169362 images were created from 1000 time windows.
Using the CNN trained with the dataset above, we try to detect LFEs and distinguish them from ordinary earthquakes.

Keywords: DONET, Machine learning, Slow earthquakes