Detection and identification of multiple-type earthquakes based on deep learning approach

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Introduction: We are monitoring seismic activities along the Nankai trough by using DONET data deployed on the seafloor in the Kumano fore-arc basin and Muroto basin. Along the Nankai trough the activities of a new earthquake category as low-frequency earthquakes (LFEs) is observed as well as ordinary earthquakes. 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. These types of events have different tectonic background for the occurrences; the ordinary earthquakes release stress in the crust, while LFEs are considered to be triggered by slow slip along the plate boundary fault. Occurrences of these events reflect diversity of earthquake generations along subduction zones. Monitoring activities of these earthquakes and investigations of their generation mechanisms will help us to understand frictional properties along faults.
We have monitored the activities of ordinary earthquakes and LFEs in the Nankai trough by using DONET observation data. Our studies of LFEs 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 of LFEs and distinguish them from ordinary earthquakes based on AI using machine learning approach. As described above, LFE signals are characterized by frequency components and signal duration. Running spectrum can represent differences in the frequency components 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 convolutional 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. We also show procedures to improve the accuracy of image recognitions.

Keywords: DONET, Machine learning, Earthquake detections

