LSTM and CNN Applications to Forecast Earthquake Magnitude Probability Distribution

*Qi Liu[1], Hiroe Miyake[2], Hiroshi Tsuruoka[3]

1. GSII, The University of Tokyo, 2. III, The University of Tokyo, 3. ERI, The University of Tokyo

An earthquake is one of the most dangerous natural disasters. And for us, earthquake is not only resulted in economic loss, but also the physiological and psychological trauma. There are two main ways to avert these kinds of loss: One is earthquake early warning, the other is earthquake prediction. Compare to the earthquake early warning, the earthquake prediction seems to be more useful for disaster mitigation, decrease damage by earthquakes, but unfortunately it is more difficult to predict with accurate physics-based ways, even sometimes is thought to be impossible. Spatial distribution of earthquakes has some relationships with the structure of the Earth. Temporal distribution of earthquakes has some relationships with mechanical properties and stress state of the Earth. There are a lot of studies that count earthquake events for finding several laws of earthquakes with great achievements: Omori formula, Modified Omori formula, ETAS model, and etc. These traditional models had good performance on the aftershock forecasting, but are not good enough to the mainshock forecasting. The earthquake occurrence is generally according to the Poisson distribution which follows the power law. This kind of distribution is meaningful because the earthquake event has same probability of occurrence per unit time. This is one of reasons why it is difficult to forecast mainshocks.

With the development of computer science, several new technologies have been created: liner regression, nonlinear regression, and classification based on machine learning. According to updates of computer hardware, not only original machine learning such as Random Forest (RF), Support Vector Machines (SVM), and Neural Network (NN) has been used for the earthquake data mining but also several Neural Network deep learning methods has been abundantly used for these forecasting problems. Nowadays imagine identification technology based on Convolutional Neural Network (CNN) and text generation technology based on Recurrent Neural Network (RNN) are the most representative technologies. These two kinds of most useful Neural Network models are also widely used for spatial data mining as well as temporal data mining. We consider to combine these two Neural Networks to find spatio-temporal relationship among earthquakes at different positions and to perform earthquake event forecasting by taking advantage of this relationship.

At 14:46 on 11 March 2011, the Tohoku earthquake occurred. It is well-known that predicting this kind of a giant earthquake is most helpful to us for disaster mitigation. In this study, we use earthquake event data within 100 km depth in 2000-2010 from the JMA (Japan Meteorological Agency) unified catalog, and sort out one-day JMA magnitude probability distribution values (events number, magnitude average value, maximum magnitude value, and standard value) as one dataset per spatial grid to cover the catalog over Japan. Through supervised learning, we forecast earthquake magnitude probability distribution based on LSTM RNN (Long-Short Term Memory Recurrent Neural Network) and CNN (Convolutional Neural Network) prior to the 2011 Tohoku earthquake.

Keywords: machine learning , earthquake forecasting, Recurrent Neural Network

