EARTHQUAKE ESTIMATION WITH LSTM NETWORK MODEL

Doç.Dr.Emre Ercan [1]; Nuh Muhammed Pişkin[2]
[1]İnşaat Mühendisliği Bölümü Ege Üniversitesi,İzmir Türkiye ;
[2]İnşaat Mühendisliği Bölümü Ege Üniversitesi İzmir Türkiye
[1]emre.ercan@gmail.com; [2] nmpiskin@gmail.com

Abstract

Recurrent neural networks (RNN) have an increasing use in the field of machine learning recently with their memory structure. Long-short term memory (LSTM) models, an enhancement of these networks, are commonly used to evaluate sequential data. In this study, the use of LSTM networks in regional earthquake prediction is ensured. For this purpose, a five-layer deep LSTM network model is prepared. For the application of this model in Turkey for between 25.774 West, 27.442 East latitudes with 39.166 North, 38.145 South longitudes are selected. The data given here are the earthquake data of the province of Izmir above the intensity of 2.5 from 1950 to 2019. Earthquakes that occur in a sequential manner in this circular area depending on time have been used in the training of the LSTM network. The results of the completed network were tried on different layers and the model with the highest accuracy was determined. The results obtained are presented and discussed.

Keywords: Recurrent neural networks; LSTM networks; earthquake prediction; deep neural networks

1.Introduction

The earthquakes that cause big and sudden destruction are natural disasters that negatively affect the lives of thousands of people. Severe earthquakes have caused many psychological impacts as well as loss of life and goods. Marmara earthquake in history as the greatest natural disaster that Turkey experienced.

Natural disasters such as earthquakes cannot be prevented because they have not given a warning before. Therefore, the issue of earthquakes has always been an interesting subject. With the advances in machine learning, artificial intelligence based earthquake studies have shown efficiency. There are many earthquake studies based on artificial neural networks (ANN) in the literature.

Neural networks are nowadays widely used in many different fields for pattern recognition and classification problems [1]. Nevertheless, few studies have used neural networks for earthquake prediction.

Alves [2] was one of the first authors to propose neural networks for earthquake prediction. It was successfully used with the seismicity of the Azores, but a large time position window was used.

Panakkat and Adeli (2007) [3] proposed three different ANN - a feed - forward Levenberg - Marquardt back - propagation neural network, a recurrent neural network and a radial basic function to estimate the earthquake magnitude in Southern California and San Francisco Bay. After evaluating all the seismicity indicators they applied, recurrent neural networks provided the best estimation accuracy on average. Panakkat and Adeli (2009) [4], the same authros predicted earthquake time and location in Southern California, using this time an improved version of the recurrent neural network. In particular, they computed several sets of earthquakes regarding the latitude and longitude of the epicentral location as well as time of occurrence of the following earthquake.

Madahizadeh and Allamehzadeh [5] studied the concentration and trend of the 2008 Sichuan earthquake. In 2011, Moustra et al. [6] evaluated the accuracy of artificial neural networks for earthquake prediction using a time series of magnitude data or seismic electric signals in Greece. The reported average accuracy was 80.55% for all earthquakes, but only 58.02% for larger events (greater than 5%). After analyzing the analysis with different inputs, they concluded that ANN training is a key factor that can greatly increase the quality of the results.

In this article, a deep model of LSTM networks, which has recently become popular in the field of machine learning and has been increasingly used, has been used in earthquake prediction. For this purpose, a deep LSTM model has been designed and the earthquakes that have been performed around the center determined for the applications of this model have been used as input data. It is ensured that the model predicts the next occurrence of the earthquake at certain successive intervals.

2. Recurrent Neural Network

Recurrent Neural Network (RNN) are the artificial neural network class where the connections between the units form a directed loop. RNN, is augmented forward-feed neural networks that are reinforced by the addition of edges along the adjacent time steps, bringing the time concept to the normal neural network model. This allows dynamic temporal behavior. Unlike feeder neural networks, RNNs can use their input memory to process arbitrary sequences of inputs. The main purpose of recurrent neural networks is to use sequential information. In a conventional neural network we assume that all inputs (and outputs) are independent of each other. RNNs are called repetitive because they perform the same task for each element of an array, the output depends on previous calculations. Another way to think about RNNs is that they carry “memory” that collects information about what has been calculated so far. Theoretically, RNNs can arbitrarily use information from long sequences, but in practice are limited to only a few steps back. Fig 1. A typical RNN:

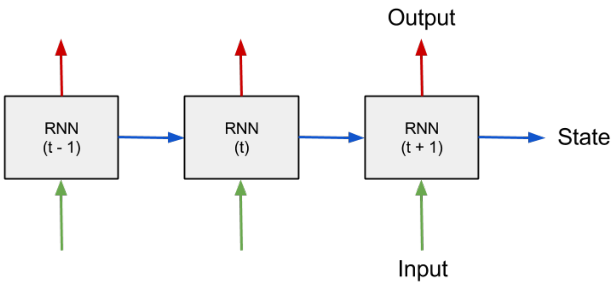


Figure 1 RNN Network

Long Short Term Memory Networks - often referred to as "LSTM"- is a special type of RNN that can learn long-term dependencies. These were introduced by Hochreiter & Schmidhuber (1997) [7]. They work tremendously on a variety of problems and are now widely used. LSTMs are clearly designed to avoid long-term dependence. Remembering knowledge for a long time is practically the default behavior, it is not something they are struggling to learn. All recurrent neural networks are in the form of a repeating neural network module chain. LSTMs have successive structures in succession. However, the next part has a different structure. Instead of a single neural network layer, there are four parts that interact in a very specific way. Fig 1. A typical LSTM:

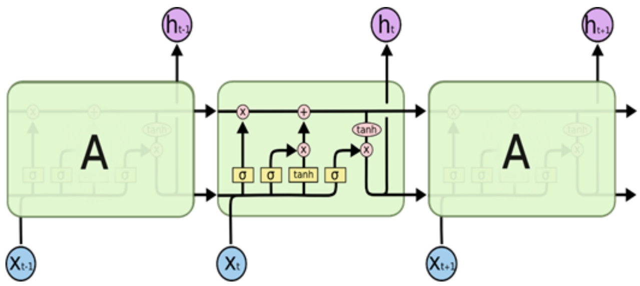


Figure 2 LSTM Network

3. Recommended Deep LSTM Network Approach For Earthquake Estimation

For this study, earthquake data greater than 2.5 were used for the severity of Izmir province between 25.774 West, 27.442 East latitude and 39.166 North, 38.145 south longitude between 1950 and 2019 years. The United States Geological Survey (USGS) Earthquake Hazards Program was used to obtain Earthquake Data. Figure 2 shows a screenshot of a query result made on the region designated for the study.

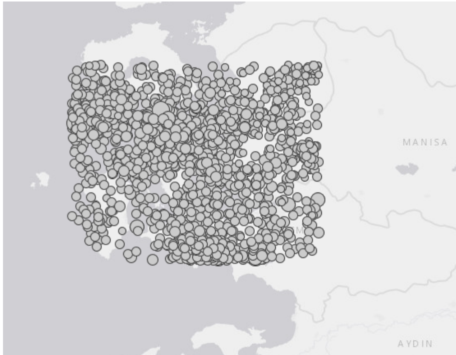


Figure 3 Earthquakes in the Izmir region between 1950-2019 years.

4. LSTM Network Prediction Model

Experiments were conducted with different layered network models for earthquake prediction. Accuracy values obtained by the studies have been evaluated and a suitable model has been decided. Accuracy evaluation was performed according to the mean square error values of the test results. The most appropriate model is the LSTM layer of 100 and 50 units, respectively. In order to prevent memory in deep networks, 0.2 dropout were used in each LSTM layer.

5. Experimental Results

The squence length-SL used in the study for the earthquake predictions determines how much time period will be used for the earthquake to be estimated. If the parameter SL is set to 15, then the intensity of the next earthquake is estimated after every 15 earthquakes. With the sliding window logic, this process continues by shifting the data on the data. In this study, results were obtained with different SL values. Firstly, SL values were determined as 10, 25 and 50 respectively and applied on each data set and results were given. 300 repetition steps (epoch) and 10 batch_size were used in the training phase of the deep model. Then, for the SL values 25 and 50, 1000 repetition steps (epoch) and 10 batch_size were used to make learning more clear and to minimize the error.
And these results were evaluated.

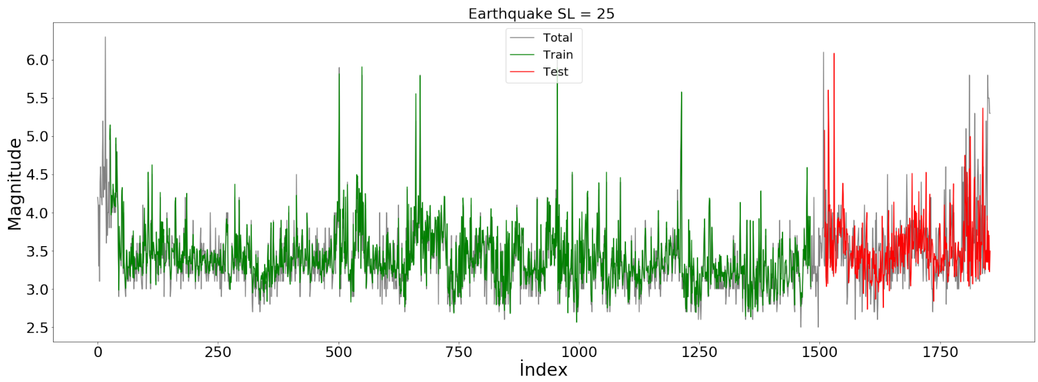
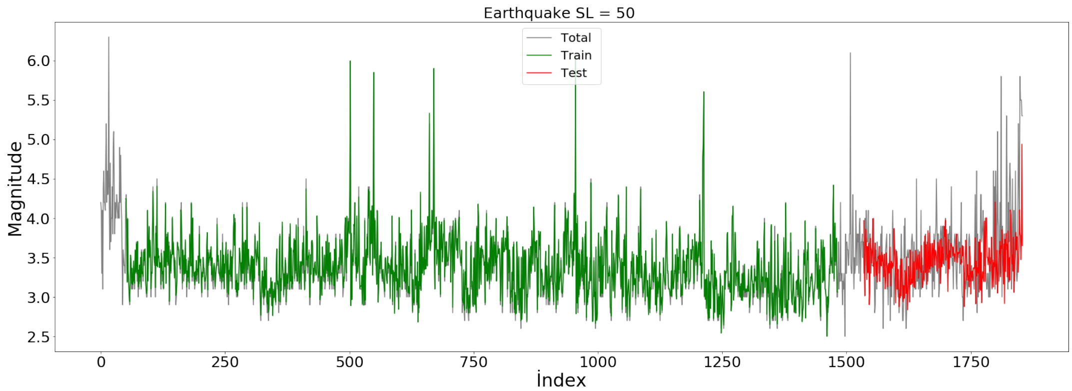


Figure 4. SL 25 train, test and all data



Squence Length-SL	Type	Error (RMSE)
SL = 25	**Train**	0.128763 RMSE
	Test	0.626155 RMSE
SL = 50	**Train**	0.051359 RMSE
	Test	0.528263 RMSE

Figure 5. SL 50 train, test and all data

Table 1 Error table for SL 25 and SL 50

In experimental studies, 80% of earthquake data was used for training. The remaining 20% is reserved for testing. In the experimental study, the seismic activity of İzmir city center between 1950 and 2019 was recorded as 1855 in total. In Figure 4, 5, test and prediction charts of data trained and tested with the LSTM model are given. The difference between estimated and actual earthquakes is noteworthy.

6. Conclusion

Earthquake prediction is a highly complex and arguably intractable problem. Some scientists may argue earthquakes cannot be predicted scientifically. However, the earthquake magnitude, epicenter position and time estimation may be of great value for the emergency management and hazard preparation perspective, even in a sense [7]. Therefore, even if we cannot predict the earthquakes one hundred percent, we should make enough inferences to take necessary measures. In order to contribute to the studies conducted in this field, a model has been developed with LSTM to estimate the earthquake magnitude. Even if we did not get effective results in earthquake magnitude of 3.5 and above, remarkable results were obtained. New studies will be carried out with different inputs to improve model and accuracy. And as a result of these studies, it is aimed to produce systems that can intervene in an early period in order to reduce the effects of the earthquake.

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