A SURVEY OF RISK TAKING ANALYSIS AND PREDICTION OF MAGNITUDE AND TIME OF EARTHQUAKE IN SAN FRANCISCO BY ARTIFICIAL NEURAL NETWORK

Abouzar CHERAGHI
PhD Civil Student, Islamic Azad University, Larestan, Iran
Aboozarch2005@yahoo.com

Akbar GHANBARI
PhD Civil, Islamic Azad University, Larestan, Iran
ghanbari12345@yahoo.com

Keywords: Risk Analysis, Earthquake Prediction, Artificial Neural Network, Earthquake Occurrence Time, Earthquake Magnitude.

ABSTRACT

As artificial neural network showed its efficiency in prediction of time series and temporal-spatial series, in recent years, some efforts are made to use artificial neural network in prediction of temporal and spatial distribution of earthquakes. In this research, by the study of the history of activities and previous movements of dynamic faults in 121 to 123 longitude and 37 to 39 latitude with very complex dynamic system in earthquake-field regions of San Francisco, a simplified image of fault is made by artificial neural network and we can determine the efficiency of artificial neural network by this model. By the analysis result, the released energy of earth is determined to a definite date.

The databases include 950 data including occurrence time, distance from fault plane, focal depth and earthquake magnitude. The total data were separated into network training and network test after normalization by STATISTICA software. The present study applied 782 data in terms of occurrence time, 30% of data (232 data) were used as test and 70% of data (549 data) were used as training. Each series had real input and outputs and finally the network could predict output and a suitable prediction network is the one with the least difference of real output and predicted output.

By artificial neural network, the earthquake occurrence and magnitude are predicted. The results showed that proposed method is good for earthquake prediction. The maximum error value of test is 0.0466 or 4.66% and it indicated the validity of prediction.

INTRODUCTION

In the current world, due to the lack of assurance, decision making process is very difficult. Various tools are created to help the decision makers. Risk management by unique solutions and strategies could create systematic methods for engineering issues. To consider scientific aspects, all beneficiaries of risk analysis, considered a united framework as necessary. Earthquake prediction is one of the most important risk management tools. Thus, seismic evaluation is necessary in earthquake-stricken regions in the world. In this study, the obvious features of risk management are used and by earthquake prediction and management method of earthquake risk, various frameworks are investigated. San Francisco is exposed to earthquakes of intra-plane ruptures and by stud of satellite images and air magnetic maps, geotectonic, geology and etc., we found about tens of active faults in this region. Great seismic faults (Figure 1) indicated the activity history and its destructive effect in past and future earthquakes. Prediction of natural events as earthquake is one of the desires of human being (Geller, 1997). The outcomes of using the prediction results were always a challenging issue. Despite this fact, this question is raised is there earthquake prediction and it is the subject of many researches in the past decades (Wyss, 1997; Allen et al., 1997).

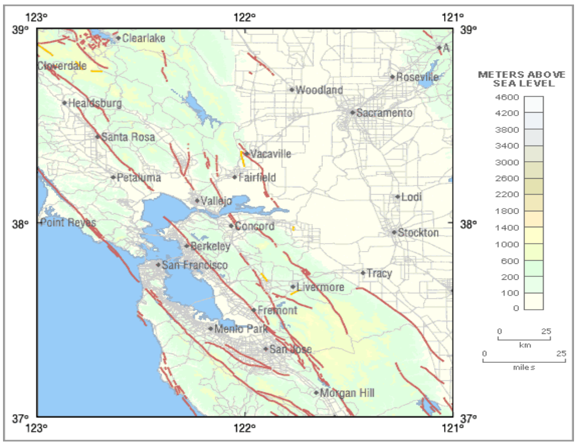

Figure 1. Great and seismic faults of San Francisco

The national research council of US predicted earthquake as: Earthquake prediction includes a great interval of earthquake, the geographical region in which earthquake is occurred, the time interval in which earthquake is occurred by high precision [4]. Thus, prediction of earthquakes is divided into the followings in terms of their time zone:

1-Long term (one decade time) 2-Midterm (for some years)

3-Short-term (for some weeks) 4-Moment (for some days or less)

As artificial neural network showed its efficiency in prediction of time series and temporal-spatial series, in recent years, some efforts are made to use artificial neural network in prediction of temporal and spatial distribution of earthquakes. In this research, by the study of the history of activities and previous movements of dynamic faults in 121 to 123 longitude and 37 to 39 latitude with very complex dynamic system in earthquake-field regions of San Francisco, a simplified image of fault is made by artificial neural network and we can determine the efficiency of artificial neural network by this model. By the analysis result, the released energy of earth is determined to a definite date.

THE MECHANISM OF ARTIFICIAL NEURAL NETWORK

The present study was analyzed by artificial neural network by STATISTICA software and the features were including: feed forward neural network, back error propagation, sigmoid activation function, Mean square error.

The software uses two series of data for network training: training and test series. In other words, the data used for training series are separated from test series data.

The databases include 950 data including occurrence time, distance from fault plane, focal depth and earthquake magnitude. The total data were separated into network training and network test after normalization by STATISTICA software. The present study applied 782 data in terms of occurrence time, 30% of data (232 data) were used as test and 70% of data (549 data) were used as training. Each series had real input and outputs and finally the network could predict output and a suitable prediction network is the one with the least difference of real output and predicted output.

4 inputs and 2 outputs are defined for neural network shown in Figure 2. The distance of earthquake center to causative fault, the time distance of occurred earthquake to the last previous earthquakes, focal depth and magnitude of earthquake as input and occurrence time and earthquake magnitude were considered as output to make artificial neural network. Due to using Sigmoid function, all inputs of network should be normalized in order that the network can determine, separate and classify the data and finally they had correct learning of models. Equation (1) was used for normalization.

$$x_{normalized} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

Where x normalized is normalized data, x non-normalized data, xmin is minimum data and x max is maximum data in data set.

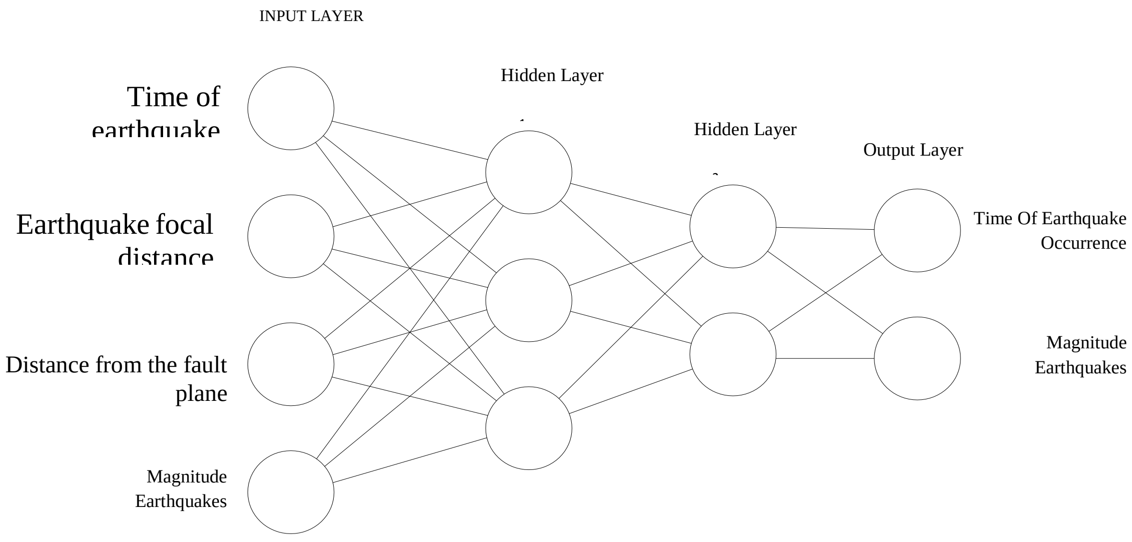

Figure 2. A view of input and output data in artificial neural network

One of the important issues in seismic studies is finding the relations between various components of earthquake with each other.

Equation (2) defines the equation of released energy and earthquake magnitude expressed by Gutenberg and Richter as empirically:

$$[Log_{10} E = 11.8 + 1.5M] \quad (2)$$

Where E is vibration energy of earthquake in Erg and M magnitude of low magnitude earthquakes. The applied data in the study are introduced as:

The time of earthquake occurrence: time of earthquake occurrence is extracted by day and hour of earthquake in USGS databases. The information was available since 1973/9/17 to 2012/3/1 as continually.

Focal distance of earthquake: The focal distance of occurred earthquakes was available in earthquake statistics and it is normalized in equation (2).

Distance from causative fault: Based on defining earthquake distance, its distance from the closest fault is considered as the distance from causative fault.

Earthquake magnitude: In earthquake statistics, the available data is earthquake magnitude (Mb, Ms, MI) in Richter. To use these values in data analysis, according to equation (2), they are turned into released energy of earth activities and its cumulative values are calculated in the studied time.

Network training algorithm, back propagation and transmit function, bilinear sigmoid, error calculation method, absolute mean, initial noise 0.001 and learning rate of first, second hidden layers and output were 0.4, 0.03 and 0.01, respectively. The momentum of first, second hidden layer and output were 0.02, 0.01 and 0, respectively. The statistics of training and test records of the network are selected randomly by a computer plan. STATISTICA software was used for data analysis and after 10000 repetitions, the mean error of training and test and maximum error of training and test were 0.02033 and 0.020959, 0.068351 and 0.04663, respectively.

THE RESULTS

Neural network predicted earthquake with acceptable precision. These results are in two sections of magnitude prediction and the time of earthquake occurrence.

1. EARTHQUAKE MAGNITUDE PREDICTION

Figure 3 shows the results of the comparison of the normalized data of earth released cumulative energy in a time with the predicted values. As shown, in test data, predicted value is consistent with the existing values. The mean error of network in test data is 0.005 or 0.5% and maximum error is 0.033 or 3.3%. Figure 4 shows the same information for non-normalized values. In this figure, the cumulative released energy of various earthquakes occurred frequently are compared with the predicted values. For example, this figure shows that if since selected time (1973) to the definite time, the released energy of earth during earthquake is 3000 million Erg, how is the predicted value? As shown in Figure, the prediction of cumulative released energy of earth is very exact. Figure 5 indicates released cumulative energy of earth in time. In this figure, the predicted values of energy are compared with the measured values. For example, this figure shows that the sum of released energy of earth in 2000 days after the reference time is 2760 million Erg and its predicted value is 2740 million Erg and it has good consistency. Figure 6 compares the magnitude of the occurred earthquakes in Richter with the predicted earthquakes. In this figure, the magnitude of earthquakes is calculated by the cumulative released energy of earth. The comparison of the values showed that earthquake prediction had acceptable consistency with the occurred values.

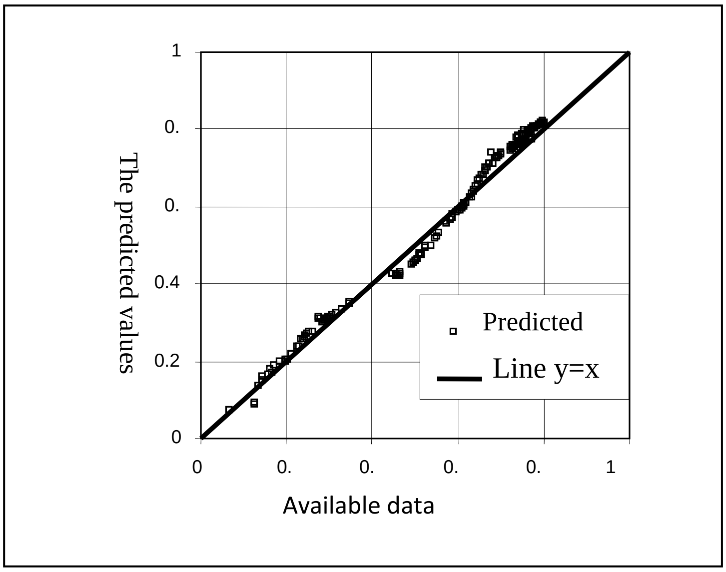

Figure 3. Comparison of the normalized predicted values of earth released energy during earthquake with the existing data

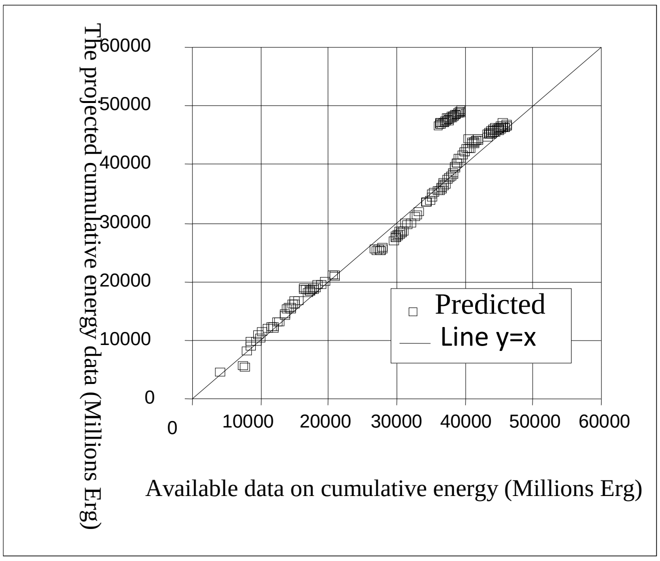

Figure 4. Comparison of the normalized predicted values of earth released energy during earthquake with the existing data

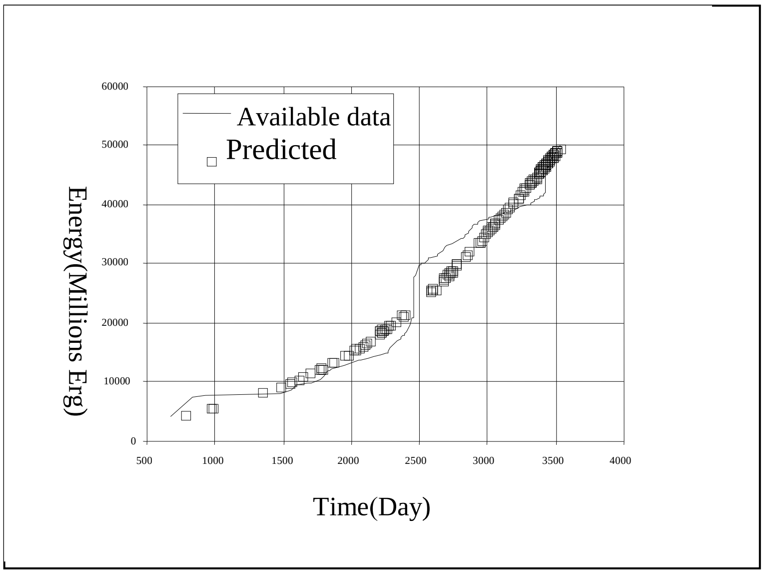

Figure 5. Comparison of the normalized predicted values of earth released energy during earthquake with the existing data

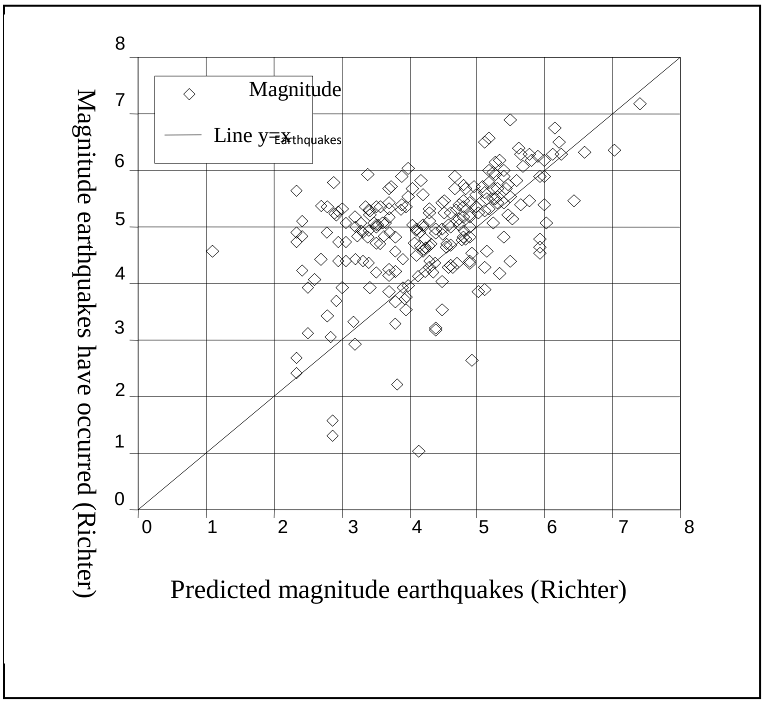

Figure 6. The comparison of the magnitude of predicted earthquake (in Richter) with occurred earthquakes in San Francisco

2. PREDICTION OF THE TIME OF EARTHQUAKE OCCURRENCE

Figure 7 shows the normalized results of the prediction of earthquake occurrence time for test data of network. The error of test is similar to the information of section a. Figure 8 shows the results of prediction of the time of earthquake time to the time source (1973).

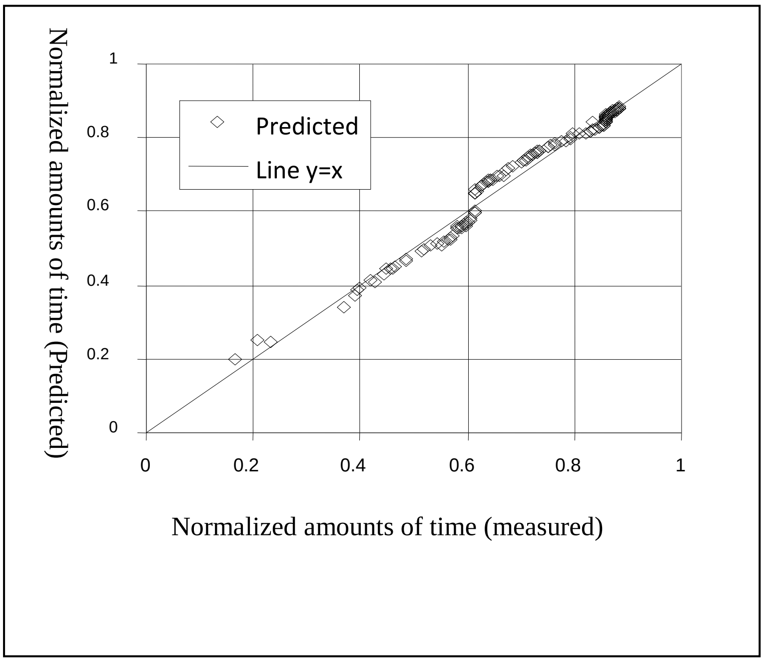

Figure 7. The comparison of the normalized results of the time of predicted earthquake occurrence with measured earthquake

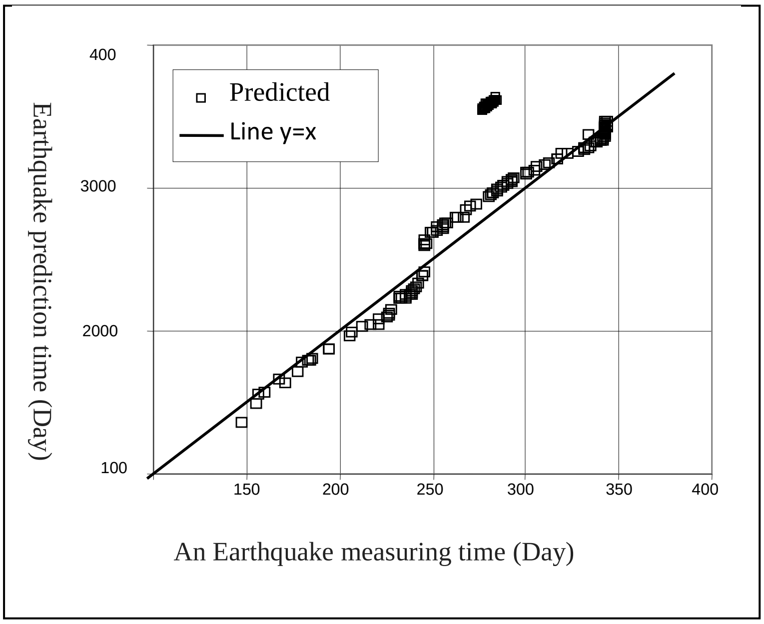

Figure 8. The results of prediction of the time of earthquake occurrence to the origin time (1973)

Figure 8 shows the precision of occurred earthquakes prediction. For example, we can say the time of earthquake occurred after 2000 days of time source, is predicted 2014 with two weeks of error.

Table 1. The results of prediction of magnitude and released energy from June 2012 to May 2013

Probable date of earthquake occurrence	Cumulative energy from source time (1911)(Millions Erg)	Cumulative energy of prediction time (Millions Erg)	The amount of released energy at any time	Magnitude of probable earthquake With the assumption of the lack of earthquake before that (Richter)	Magnitude of probable earthquake with the assumption of occurrences of earthquake before it (Richter)
June2012	49243.26	-	-	-	-
July2012	49335.96	92.70	92.70	3.56	3.56
August2012	49345.86	102.60	9.90	4.63	3.07
September2012	49383.60	140.34	37.74	4.84	3.96
October2012	49402.44	159.18	18.84	4.92	3.50
November2012	49430.94	187.68	28.50	5.03	3.78
December2012	49522.80	279.54	91.86	5.30	4.56
January2013	49541.40	298.14	18.60	5.34	3.49
February2013	49569.48	326.22	28.08	5.40	3.77
March2013	49660.08	416.82	90.60	5.57	4.55
April2013	49678.38	435.12	18.30	5.59	3.48
May2013	49706.10	462.84	27.72	5.64	3.76

3. THE PREDICTION OF FUTURE EARTHQUAKES

As it was said before, the time of earthquake occurrence to the time source and earth released energy was investigated. This means that we can predict total released energy of earth within the next six months. The fact that his energy is released suddenly or not is predicted. Above, all we can predict how much unreleased energy is in earth and it should be released in the past three months. The significance of the study showed that as there are no small earthquakes in the past months, we can predict the magnitude of probable earthquake. The above items can be defined regarding earthquake occurrence time. TO predict occurrence time and magnitude of future earthquakes in artificial neural network, the released energy of earth is normalized during various times and is added as input to the testing section. The results are shown in Table 1. For example, based on the data of this table, we can predict the earthquake occurrences with magnitude 5.3 Richter in December 2012 on condition that no earthquake is occurred before that and if the previous earthquakes are occurred, an earthquake with magnitude 4.56 Richter is probable.

CONCLUSION

By artificial neural network, the earthquake occurrence and magnitude are predicted. The results showed that proposed method is good for earthquake prediction. The maximum error value of test is 0.0466 or 4.66% and it indicated the validity of prediction. It is predicted in the study as no earthquake is occurred in San Francisco by May 2013, an earthquake with magnitude 5.64 Richter is probable.

REFERENCES

Allen MN, Edwards W, Hall WJ, Knopoff L, Raleighn CB, Savit CH, Toksoz MN and Turner RH (1997) Predicting Earthquakes: A Scientific and Technical Evaluation-with Implications for Society, Panel on Earthquake Prediction of the Committee on Seismology, Assembly of Mathematical and Physical Sciences, National Research Council, U.S. National Academy of Sciences, Washington DC

Geller RJ (1997) Earthquake Prediction: A Critical Review, Geophysical Journal International, Vol. 131, pp: 425-450

Kossobokov VG, Romashkova LL, Panza GF and Peresan A (2002) Stabilizing Intermediate-Term Medium-Range Earthquake Prediction, Journal of Seismology and Earthquake Engineering, Vol.4, Nos. 2&3, Tehran, I.R. Iran

Wyss M (1997) Can Not Earthquakes Be Predicted?, Science, Vol. 278, pp. 487-488