IJE TRANSACTIONS A: Basics Vol. 32, No. 4, (April 2019) 467-473

International Journal of Engineering

Journal Homepage: www.ije.ir

# Statistical Prediction of Probable Seismic Hazard Zonation of Iran Using Self-organized Artificial Intelligence Model

A. Sivandi-Pour*, E. Noroozinejad Farsangi

*Faculty of Civil and Surveying Engineering, Graduate University of Advanced Technology, Kerman, Iran*

*PAPER INFO*

*Paper history:*
Received 04 January 2019
Received in revised form 14 February 2019
Accepted 07 March 2019

*Keywords*:
*Earthquake Prediction*
*Seismic Risk*
*Self-organized Artificial Neural Networks*
*Statistical Analysis*
*Zonation Map*

*ABSTRACT*

The Iranian plateau has been known as one of the most seismically active regions of the world, and it frequently suffers destructive and catastrophic earthquakes that cause heavy loss of human life and widespread damage. Earthquakes are regularly felt on all sides of the region. Prediction of the occurrence location of the future earthquakes along with determining the probability percentage can be very useful in decreasing the seismic risks. Determining predicted locations causes increasing attention to design, seismic rehabilitation and evaluating the reliability of the present structures in these locations. No exact method has been approved for predicting future earthquake parameters yet. In recent years, more attention is paid to the earthquake magnitude prediction, but no study has been done in the field of probable earthquake occurrence hazard zonation. In this study, locations of future earthquakes in Iran were predicted by self-organized artificial neural networks (ANN). Then probable seismic risk zoning map was drawn by the statistical analyses, and the results indicated that the maps can properly predict future seismic events.

***doi**: 10.5829/ije.2019.32.04a.02*

## NOMENCLATURE

| | | | |
|---|---|---|---|
| $i^*$ | Winner neuron index | $\Phi(r_i,r_i^*)$ | Neighborhood function |
| $\rho$ | Learning rate | $w_i$ | Nuron Weight |

## 1. INTRODUCTION

Iran is one of the most seismic prone countries in the world, as more than 90% of the country falls within an active seismic zone, the Alpine-Himalayan belt. Iran is surrounded by tectonically active zones. Historical information and all available records show that approximately 130 large earthquakes have taken place in the past. The devastating Bam earthquake killed several thousand and demolished a city of 80,000 people located in a sparsely populated area at the southwestern of Iran. The Bam earthquake has been one of the major catastrophic events that have happened in the recorded history of Iran. Earthquake parameters prediction is the most important problem in seismological studies. In recent years, seismologists and earthquake engineers have focused on earthquake prediction related topics to reduce the earthquake risks. Estimating the future earthquakes occurrence probability in the forecasted zones has a fundamental role in increasing attention to structures' design in the studied locations and also speed up the seismic rehabilitation of the existing structures in these locations [1–11].

Various methods such as seismic data analyses [12], pre-markers control [13], probabilistic and statistical models [14], and artificial intelligence [15] have been used to predict the earthquake components. Many studies have been done on earthquake prediction based on artificial intelligence. These studies would be classified into two types of those based on neural networks and

---

*Corresponding Author Email: *a.sivandi@kgut.ac.ir* (A. Sivandi-Pour)

Please cite this article as: A. Sivandi-Pour, E. Noroozinejad Farsangi, Statistical Prediction of Probable Seismic Hazard Zonation of Iran Using Self-Organized Artificial Intelligence Model, International Journal of Engineering (IJE), IJE TRANSACTIONS A: Basics Vol. 32, No. 4, (April 2019) 467-473

those based on fuzzy systems. Neural networks such as self-organization feature map (SOFM) are much more popular techniques than fuzzy systems in earthquake parameters prediction. According to this fact that seismic patterns are not clear before major earthquakes occur, the application of advanced statistical models such as artificial neural networks is undeniable. Advanced machine learning based methods have the ability of approximate reasoning and can deal with complex issues indirectly. In comparison to classic methods of pattern identification, neural networks design is dependent on real data directly, so these designs are known as free models. Old patterns can be replaced by new patterns in time-related components applications such as earthquakes catalog [16, 17].

Yamashina [18] used a criterion of magnitude difference to make an alarm for impending larger earthquakes. This method for earthquake prediction was confirmed to be useful for the events preceded by small earthquakes. Borghi et al. [19] reported on a success story consisted of a straightforward integration between a long-lasting lithosphere-scale rock mechanics experiment towards a useful integration between tested earthquake prediction algorithms and GPS monitoring. Su and Zhu [20] applied ANN to predict earthquake influence in the design of earthquake response spectra and seismic micro-zonation in Tangshan city of China. Külahci et al. [13] used a three-layer ANN algorithm to model the earthquake prediction process in the East Anatolian Fault System (EAFS). The proposed ANN system employs individual training strategy with fixed-weight and supervised models leading to estimations. Sharma and Tyagi [21] applied ANN to learn the cyclic behavior of seismicity in the independent seismogenic sources to predict their future trends. Moustra et al. [15] evaluated the performance of ANN in predicting earthquakes occurrence in the region of Greece by using different types of input data. Yazdani and Kowsari [5] predicted the earthquake ground-motion equations for the sites with different soils conditions in the north of Iran based on non-deterministic models and Bayesian updating. The predictive equations are developed for peak ground acceleration and response spectra for soil and rock sites and compared to the available ground-motion data [7]. Mirrashid [22] investigated the prediction of future earthquakes that would occur with a magnitude of 5.5 Richter scale or greater using an adaptive neuro-fuzzy inference system (ANFIS). The results showed that ANFIS had higher accuracy to predict earthquake magnitude [22]. Giardini et al. [8] focused on the summary of the ordered network structure of earthquakes greater than 8.0, supplements new information of three earthquakes greater than 8.0 occurred in Nepal (1833, 1934, and 2015). To predict earthquakes, 2D and 3D network structures were optimized in their study [8]. Yang and Yang [17] proposed a new multi-step prediction method of empirical mode decomposition-extreme learning machine (EMD-ELM) for the prediction of strong ground motions. Chaudhuri et al. [23] have implemented ANFIS to predict the seismic indicators of large earthquakes over the Indo-Himalayan region. The investigated database for training the proposed network covered the seismic events occurred from 1995 to 2015. The results indicated that there is good conformity between the predicted values by ANFIS and the new earthquakes [23].

In this research, properties of the occurred earthquakes with a moment magnitude ($M_w$) greater than 5.5 Richter scale occurred in Iran between the years of 1903-2017 have been gathered from different seismic databases. Self-Organization Feature Map (SOFM) and statistical analysis were applied for earthquake prediction in Iran. SOFM categorized high volume of input data (earthquake catalog) simultaneously to identify seismic patterns appropriately. In spite of most of the available statistical methods, the implemented approach doesn't need many hypotheses. In the final stage, according to the performed statistical review of predicted data, earthquake occurrence probability has been evaluated and probable seismic hazard zoning maps were drawn.

## 2. GEOPHYSICAL AND SEISMICITY CHARACTERISTICS OF IRAN

The main goal of this research is to predict the probable location of the next earthquakes by earthquakes that occurred in the past. For this purpose, three input variables (longitude, latitude, and magnitude) for each

**TABLE 1.** The greatest earthquakes in Iran (1900-2017)

| Date | Region | Death rate | Magnitude (Mw) |
|---|---|---|---|
| 23 Jan. 1909 | Silakhor | 5,000 | 7.3 |
| 1 May 1929 | Koppeh Dagh | 3,800 | 7.2 |
| 6 May 1930 | Salmas | 2,500 | 7.2 |
| 2 Jul. 1957 | Sang Chai | 1,300 | 7.1 |
| 13 Dec. 1957 | Sahneh | 1,130 | 7.1 |
| 1 Sep. 1962 | Bu'in Zahra | 12,000 | 7.1 |
| 31Aug. 1968 | Dasht-e Bayaz | 7,000 | 7.3 |
| 10 Apr. 1972 | Southern | 5,100 | 7.1 |
| 16 Sep. 1978 | Tabas | 15,000 | 7.4 |
| 11 Jun. 1981 | Kerman | 3,000 | 6.9 |
| 20 Jun. 1990 | Rudbar-Manjil | 40,000 | 7.4 |
| 10 May 1997 | Birjand-Qayen | 1,500 | 7.3 |
| 26 Dec. 2003 | Bam | 31,000 | 6.6 |
| 12 Nov. 2017 | Sarpol-e Zahab | 630 | 7.3 |

record were used. Since 1900, at least 126,000 fatalities have resulted from earthquakes in Iran. Table 1 shows the largest past earthquakes as reported by many seismological agencies.

Seismic data collection is required as inputs and outputs to form an algorithm. Based on the entered information, the algorithm is trained to present the desired results. For increasing the precision in the learning process, a large amount of input data to train the model should be gathered. The occurred earthquakes' properties between the years of 1900 and 2017 were gathered from different seismic databases in Iran [*Iranian Seismological Center*: University of Tehran, *Iran Strong Motion Network*: BHRC, and *National Center of Broadband Seismic Network of Iran*: IIEES]. The greatest occurred earthquake in this period have been Tabas and Rudbar-Manjil Earthquakes with Mw of 7.4 in Richter scale. The distribution of the occurred earthquakes greater than 5.5 is shown in Figure1. According to a high data volume of the recorded earthquakes in the region, these earthquakes were divided into three groups of 5.5 to 6.0, 6.0 to 6.5 and greater than 6.5 Richter. The statistical properties of occurred earthquakes are shown in Table 2.

The distribution of earthquake events over the years is shown in Figure. 2, which shows that almost 14% of the earthquakes have occurred between 1970 and 1980.

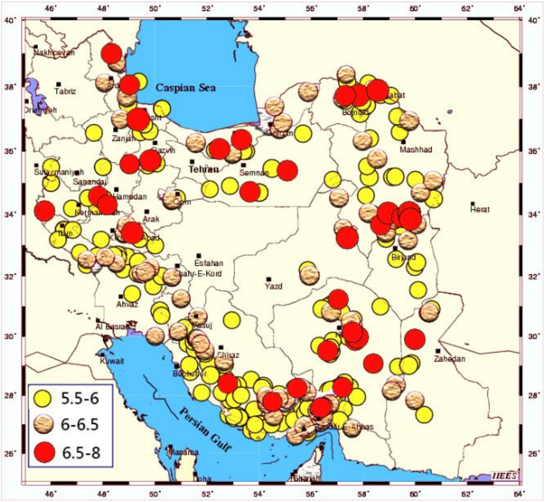

**Figure 1.** Seismicity map for the earthquakes greater than 5.5 Richter (1900-2017)

**TABLE 2.** The statistical properties of earthquakes

| Group | Number | Mw(min) | Mw(max) | Mw (mean) | Depth (min) | Depth (max) |
|---|---|---|---|---|---|---|
| 5.5-6 | 248 | 5.5 | 6.0 | 5.6 | 3 | 98 |
| 6-6.5 | 81 | 6.0 | 6.5 | 6.1 | 4 | 80 |
| 6.5-8 | 75 | 6.5 | 7.7 | 6.9 | 5 | 28 |

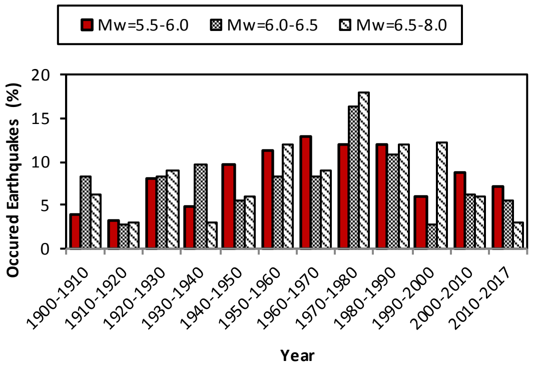

**Figure 2.** Earthquakes percentage per 10 years (1900 to 2017)

## 3. IMPLEMENTATION OF SOFM

The main target of the SOFM is to transform an incoming data of arbitrary dimension into a 1D or 2D discrete map, and doing this transformation adaptively in a topologically ordered pattern. A particular kind of SOFM known as a Kohonen Neural Network (KNN) was used in this study. KNN has a feed-forward structure with a calculation layer arranged in rows and columns. This structure consists of an array of units or neurons with a fixed position $r_i$ within the map and a variable n-dimensional weight $w_i$, where n is the dimensionality of input patterns. The weights of the neurons are updated each time. The magnitude of the change of the neuron weight depends on the topological proximity to the winner neuron, whose index i* is given below:

$$i^* = arg_i min[d_i(w_i, x^k)] \tag{1}$$

When the winner neuron is found, the weight of the *i*-th neuron is updated according to Equation (2).

$$w_i = w_{io} + \Delta w_i = w_{io} + \rho.\Phi(r_i, r_i^*)(x^k - w_i o) \tag{2}$$

where $\rho$ is the learning rate and $\Phi(r_i, r_i^*)$ is the neighborhood function.

Each neuron is fully connected to all the source nodes in the input layer. All the connection weights are initialized with small random values. Clearly, this SOFM must involve some kind of adaptive, or learning process by which the outputs become self-organized and the feature map between inputs and outputs was formed. KNN algorithm was converged, and the calculated features pattern by this algorithm showed the important statistical features of the input space. This property indicates that if input data has a nonlinear distribution in input space, the self-organized pattern is able to choose the best features for approximating the existent distribution in the input data by clustering. According to this fact that seismic patterns may not be specified clearly before big earthquakes, using pattern identification techniques with advanced statistical models such as artificial neural networks and unsupervised models such as self-organized models are suggested for identifying high-risk seismic zones [21, 24–26].

The selected KNN algorithm in this research for pre-locating has a two-dimensional topology and 81 neurons for input vectors. The neural network input is the earthquakes locations (longitudinal and latitudinal) based on three groups of magnitude. The network has been trained for 1000 repetition and is organized based on input vectors topology after the training period. Finally, the network is spread on the whole input space after repetitions completion. The applied KNN structure in this research is shown in Figure 3.

According to Figure 3, KNN generates an algorithm that has been ordered in two-dimensional network and output nodes have been severely connected to each other with local connections by arranging weights that are gone from nodes common input to the output node.

### 3. 1. Training and Convergence Trend of Neurons' Weights

Each great earthquake changes the probability of subsequent earthquakes occurrence in a distance from the seismic source and for a time period. The evaluation of earthquake risk probability for a specified time period is valid only until the subsequent big earthquake occurrence and the performed calculations are revised after the occurrence of an earthquake in each category. This statistical approach is generally originated from earthquakes being clustered in time or change in geologic and tectonic conditions. The used data for training the ANN has been shown in Figure 4. These data include location (longitude and latitude) and the magnitude of the occurred earthquakes.

Figure 5 shows the algorithmic behavior of the applied ANN from the neurons' topology point of view. According to Figure 5, neurons were begun to move toward different training groups and have diverged ANN.

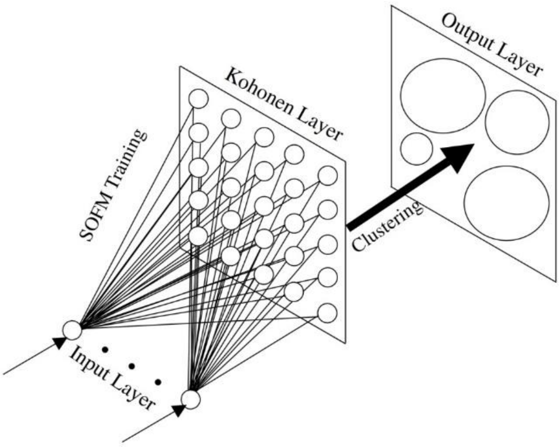

**Figure 3.** Structure of KNN used in this study

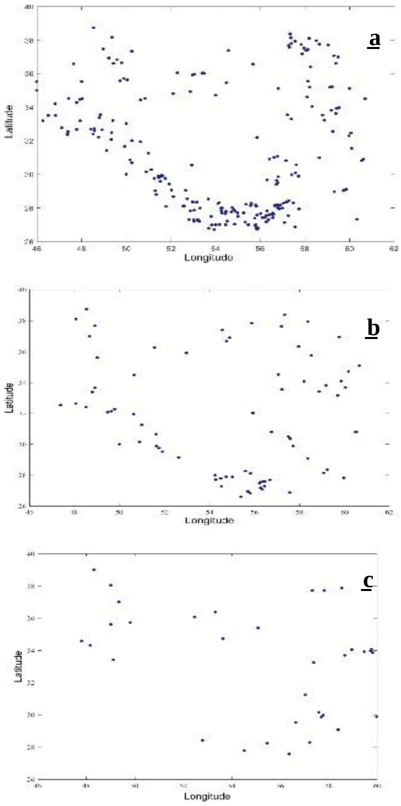

**Figure 4.** Used data to train ANN: (a) 5.5≤M<6.0 ,(b) 6.0≤M<6.5 , (c) 6.5≤M<8.0

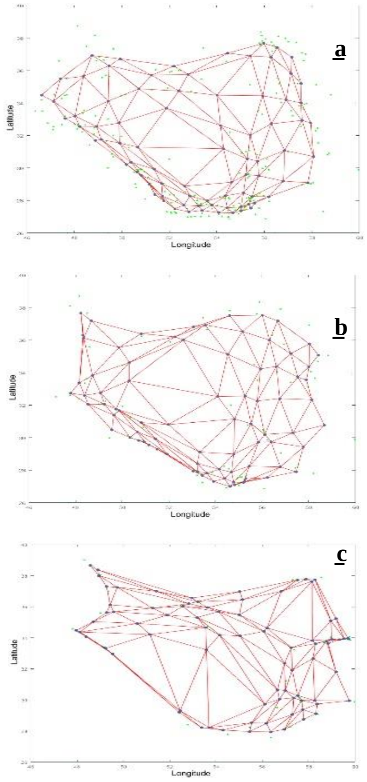

**Figure 5.** Convergence method in ANN for earthquakes: (a) 5.5≤M<6.0 ,(b) 6.0≤M<6.5 , (c) 6.5≤M<8.0

## 4. PREDICTING THE PROBABLE EARTHQUAKES LOCATION

Seismic sources ability for generating earthquake is determined based on seismicity record, and tectonic movement rate of the existed faults' dimensions in these sources. Having seismic origin and using abstraction property in KNN, it can be shown that earthquake occurrence probability is far more in the clustered sources. Therefore, if the determined alarm zone by KNN algorithm is restricted exclusively to earthquake potential sources in that zone, spatial uncertainty of the algorithm is decreased and the forecasted zone becomes smaller. Results of predicted earthquakes with magnitude greater than 5.5 are shown in Figure 6. The previous studies indicated that some perturbations in the seismicity of the region will happen before a strong earthquake occurs. Such the perturbations and their relevance to the future earthquakes is a complex phenomenon and cannot be determined by conventional statistical methods. The current methodology as shown in Figures 6(a) to 6(c) has the capability to resolve this complexity and can predict the future events with the least error.

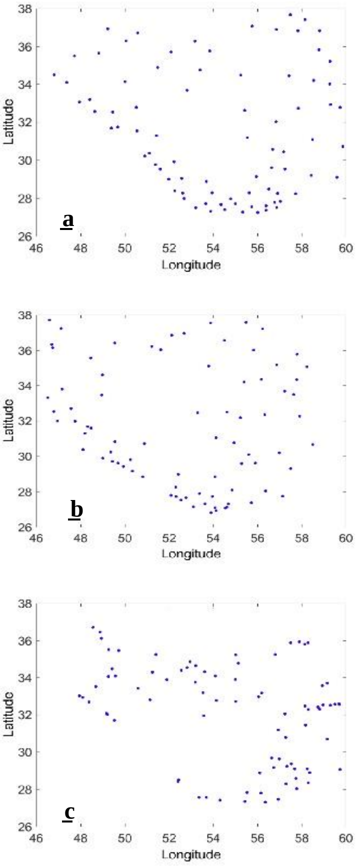

**Figure 6.** predicted earthquake locations (a) 5.5≤M<6.0 ,(b) 6.0≤M<6.5 , (c) 6.5≤M<8.0

## 5. PREDICTED PROBABLE SEISMIC HAZARD ZONING MAP

The results were processed by statistical analyses after forecasting the location of probable earthquake occurrence by KNN. Probability density function and cumulative probability function were used in order to analyze data. The occurrence probabilities of forecasted earthquakes have been 61.2, 20.1 and 18.7% for 5.5≤M<6.0, 6.0≤M<6.5 and 6.5≤M<8.0, respectively. The standard deviation for forecasted earthquakes between 5.5≤M<6.0, 6.0≤M<6.5 and 6.5≤M<8.0 were 2.3, 2.5 and 2.1, respectively. The predicted seismicity percentage zoning maps are shown in Figures 7-9 after statistical data analyses. Colored contours in these diagrams show the next earthquake occurrence probability percentage.

As can be seen in these figures, the probable locations of future events fit very well with the locations of active seismic sources in the investigated region. As indicated in Figures 7-9, the Main Zagros Reverse Fault, Doruneh Fault and the seismic sources located in the north of the country (North Alborz, Mosha, North Tehran, and North Qazvin Faults) have a higher potential to induce moderate to major earthquakes compared to other parts of the country. The predicted earthquake occurrence probabilities are shown in Table 3.

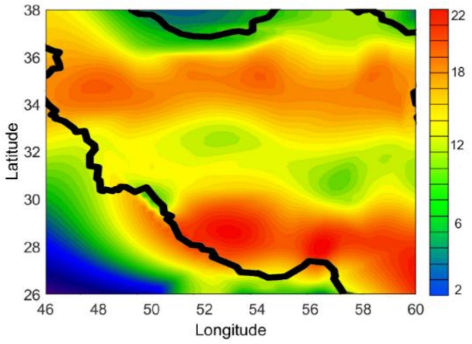

**Figure 7.** Predicted seismicity percentage zoning map for 5.5≤M<6.0

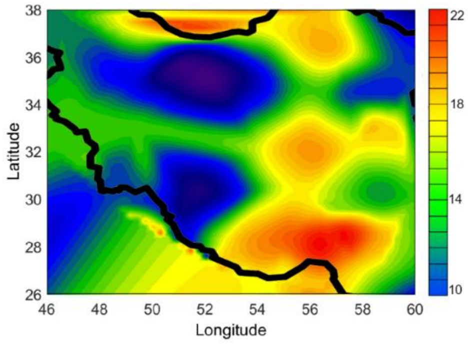

**Figure 8.** Predicted seismicity percentage zoning map for 6.0≤M<6.5

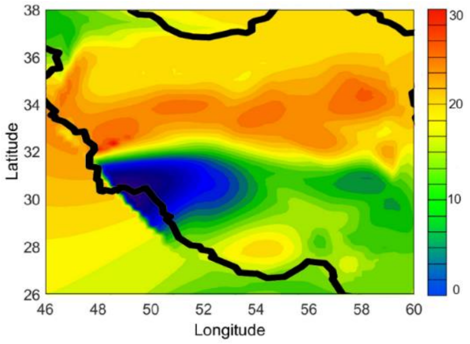

**Figure 9.** Predicted seismicity percentage zoning map for $6.5 \leq M < 8.0$

**TABLE 3.** The statistical properties of predicted earthquakes

| Group | Highest Probability | | | Lowest Probability | | |
|---|---|---|---|---|---|---|
| | Prob. (%) | Coordinates | Location | Prob. (%) | Coordinates | Location |
| 5.5-6 | 20.9 | 28.2,53.7 | South | 7.3 | 31.4,57.2 | West |
| 6-6.5 | 21.5 | 28.0,56.2 | South | 10.3 | 35.2,51.0 | North |
| 6.5-8 | 24.7 | 32.1,48.3 | West | 0.8 | 31.1,49.6 | South-east |

## 6. CONCLUSION

In this study, specifications of the occurred earthquakes greater than 5.5 Richter in Iran between the years of 1903-2017 were collected from different seismic databases. According to a high data volume of the recorded earthquakes in the region, these earthquakes were divided into three groups of 5.5 to 6 Richter, 6 to 6.5 Richter and 6.5 to 9 Richter. Locations of future earthquakes in Iran were predicted by KNN. Then probable seismic hazard zoning maps were drawn by statistical analysis.

According to the obtained maps, the highest earthquake occurrence probabilities were forecasted with the probability of 20.9% in the south zone of Iran for $5.5 \leq M < 6.0$, %21.5 in the south for $6.0 \leq M < 6.5$ and %24.7 in the west for $M \geq 6.5$. In 2018, several moderate earthquakes hit the west and south sides of the country. The proposed zonation maps have predicted such the events magnitude and locations with good accuracy. To this, the proposed methodology can be used as an alternative to current approaches for earthquake prediction.

## 7. REFERENCES

1. Amiri, G. G., Mahmoodi, H., and Amrei, S. A. R., "Probabilistic Seismic Hazard Assessment of Tehran Based on Arias Intensity", ***International Journal of Engineering - Transactions B: Applications***, Vol. 23, No. 1, (2009), 1–20.
2. Mokhtari, M., "Earthquake prediction activities and Damavand earthquake precursor test site in Iran", ***Natural Hazards***, Vol. 52, No. 2, (2010), 351–368.
3. A.Yazdani and Kowsari, M., "Statistical prediction of the sequence of large earthquakes in Iran", ***International Journal of Engineering - Transactions B: Applications***, Vol. 24, No. 4, (2011), 325–336.
4. Yazdani, A., Shahpari, A., and Salimi, M. R., "The Use of Monte-Carlo Simulations in Seismic Hazard Analysis in Tehran and Surrounding Areas", ***International Journal of Engineering - Transactions C: Aspects***, Vol. 25, No. 2, (2012), 159–166.
5. Yazdani, A. and Kowsari, M., "Earthquake ground-motion prediction equations for northern Iran", ***Natural Hazards***, Vol. 69, No. 3, (2013), 1877–1894.
6. Raeesi, M., Zarifi, Z., Nilfouroushan, F., Amini Boroujeni, S., and Tiampo, K., "Quantitative Analysis of Seismicity in Iran", ***Pure and Applied Geophysics***, Vol. 174, No. 3, (2017), 793–833.
7. Kowsari, M., Eftekhari, N., Kijko, A., Yousefi Dadras, E., Ghazi, H., and Shabani, E., "Quantifying Seismicity Parameter Uncertainties and Their Effects on Probabilistic Seismic Hazard Analysis: A Case Study of Iran", ***Pure and Applied Geophysics***, Vol. 176, No. 4, (2019), 1487–1502.
8. Giardini, D., Danciu, L., Erdik, M., Şeşetyan, K., Demircioğlu Tümsa, M.B., Akkar, S., Gülen, L., and Zare, M., "Seismic hazard map of the Middle East", ***Bulletin of Earthquake Engineering***, Vol. 16, No. 8, (2018), 3567–3570.
9. Ozturk, B., "Preliminary Seismic Microzonation and Seismic Vulnerability Assessment of Existing Buildings at the City of Nigde, Turkey", In 14th World Conference on Earthquake Engineering, Beijing, China, (2008).
10. Ozturk, B., "Seismic Microzonation Studies and Vulnerability Assessment of Existing Buildings at Nigde, Turkey", In 14th European Conference on Earthquake Engineering, ***Macedonia***, (2010).
11. Ozturk, B., "Application of Preliminary Microzonation and Seismic Vulnerability Assessment in a City of Medium Seismic Risk in Turkey", In 5th International Conference on Earthquake Geotechnical Engineering , Santiago, Chile, (2011).
12. Ram, T. D. and Wang, G., "Probabilistic seismic hazard analysis in Nepal", ***Earthquake Engineering and Engineering Vibration***, Vol. 12, No. 4, (2013), 577–586.
13. Külahcı, F., İnceöz, M., Doğru, M., Aksoy, E., and Baykara, O., "Artificial neural network model for earthquake prediction with radon monitoring", ***Applied Radiation and Isotopes***, Vol. 67, No. 1, (2009), 212–219.
14. Ashtari Jafari, M., "Statistical prediction of the next great earthquake around Tehran, Iran", ***Journal of Geodynamics***, Vol. 49, No. 1, (2010), 14–18.
15. Moustra, M., Avraamides, M., and Christodoulou, C., "Artificial neural networks for earthquake prediction using time series magnitude data or Seismic Electric Signals", ***Expert Systems with Applications***, Vol. 38, No. 12, (2011), 15032–15039.
16. Ni H. and Yin H., "Self-organising mixture autoregressive model for non-stationary time series modelling", ***International Journal of Neural Systems***, Vol. 18, No. 06, (2008), 469–480.
17. Yang, D. and Yang, K., "Multi-step prediction of strong earthquake ground motions and seismic responses of SDOF systems based on EMD-ELM method", ***Soil Dynamics and Earthquake Engineering***, Vol. 85, (2016), 117–129.
18. Yamashina, K., "Trial of earthquake prediction in Japan and a statistical test of time-shift", ***Tectonophysics***, Vol. 417, No. 1–2, (2006), 169–182.
19. Borghi, A., Aoudia, A., Riva, R. E., and Barzaghi, R., "GPS monitoring and earthquake prediction: A success story towards a useful integration", ***Tectonophysics***, Vol. 465, No. 1–4, (2009),

177–189.

20. Su, Y.-P. and Zhu, Q.-J., "Application of ANN to Prediction of Earthquake Influence", In 2009 Second International Conference on Information and Computing Science, (2009), 234–237.
21. Sharma, M. L. and Tyagi, A., "Cyclic behavior of seismogenic sources in India and use of ANN for its prediction", ***Natural Hazards***, Vol. 55, No. 2, (2010), 389–404.
22. Mirrashid, M., "Earthquake magnitude prediction by adaptive neuro-fuzzy inference system (ANFIS) based on fuzzy C-means algorithm", ***Natural Hazards***, Vol. 74, No. 3, (2014), 1577–1593.
23. Chaudhuri, S., Chowdhury, A. R., and Das, P., "Implementation of Sugeno: ANFIS for forecasting the seismic moment of large earthquakes over Indo-Himalayan region", ***Natural Hazards***, Vol. 90, No. 1, (2018), 391–405.
24. Kohonen, T., "The self-organizing map", ***Proceedings of the IEEE***, Vol. 78, No. 9, (1990), 1464–1480.
25. AllamehZadeh, M., "Prediction of aftershocks pattern distribution using self-organising feature maps", In 13th World Conference on Earthquake Engineering, Vol. 198, (2004).
26. Kohonen, T., "Essentials of the self-organizing map", ***Neural Networks***, Vol. 37, (2013), 52–65.

# Statistical Prediction of Probable Seismic Hazard Zonation of Iran Using Self-organized Artificial Intelligence Model

A. Sivandi-Pour, E. Noroozinejad Farsangi

*Faculty of Civil and Surveying Engineering, Graduate University of Advanced Technology, Kerman, Iran*

*PAPER INFO*

*Paper history:*
Received 04 January 2019
Received in revised form 14 February 2019
Accepted 07 March 2019

*Keywords*:
*Earthquake Prediction*
*Seismic Risk*
*Self-organized Artificial Neural Networks*
*Statistical Analysis*
*Zonation Map*

**چکیده**

کشور ایران به عنوان یکی از مناطق لرزه‌خیز در جهان شناخته می‌شود و اغلب زمین‌لرزه‌های مخرب و فاجعه‌بار را تجربه کرده که باعث آسیب‌های جانی و مالی زیاد شده است. پیش‌بینی موقعیت وقوع زمین‌لرزه‌های آینده همراه با تعیین درصد احتمال می‌تواند در کاهش خطرات لرزه‌ای مفید باشد. تعیین مکان پیش‌بینی شده باعث افزایش توجه به طراحی، مقاوم‌سازی لرزه‌ای و افزایش قابلیت اطمینان ساختمان‌های موجود در این مکان‌ها می‌شود. تا کنون روش دقیق و مطمئنی برای پیش‌بینی پارامترهای زلزله پیشنهاد نشده است. در سال‌های اخیر بیشتر به پیش‌بینی بزرگی زلزله توجه شده است، اما در زمینه پیش‌بینی احتمال وقوع خطر زلزله، مطالعات زیادی صورت نگرفته است. در این مطالعه، مکان زلزله‌های آینده در ایران با استفاده از شبکه‌های عصبی مصنوعی خود سازمان یافته، پیش‌بینی شده است. نقشه پهنه‌بندی احتمال خطر لرزه‌ای با استفاده از تجزیه و تحلیل آماری ترسیم شد و نتایج نشان داد که نقشه‌های استخراج شده در این تحقیق می‌توانند به طور مناسب وقایع لرزه ای را پیش‌بینی کنند.

***doi**: 10.5829/ije.2019.32.04a.02*