APPLICATION OF PATTERN RECOGNITION TECHNIQUES TO LONG-TERM EARTHQUAKE PREDICTION IN ALBORZ REGION ON IRANIAN PLATE

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ABSTRACT

Pattern recognition was one of the first methods used in geophysical application and has found wide applications in seismology. This paper is presented seismic spatial patterns recognition of west Alborz by using historical earthquake catalog data with data mining techniques. In this paper, clustering techniques are used to obtain patterns of model in behavior of seismic temporal data that can help to predict large earthquakes its future behavior by the past behavior of earthquake catalogs. This algorithm has the ability to learn new mapping for finding earthquake clustering to show all or some of the patterns before major earthquakes such as the seismic silence pattern and Doughnut pattern, these patterns in different earthquake considerably change so unsupervised learning techniques is used. In this case study after identifying Morpho-Structural nodes in western Alborz, earthquakes clusters studied and the event location of future large earthquakes has been identified by Using Kohonen Self-Organizing feature maps, the novelty of this work lies on discovering clustering-based patterns and the use of them as seismological precursor in Iran IIEES data. The results of the experiments show that recognition rates achieved with this system are much higher than those achieved when only the feature map is used the seismic silence and the Doughnut pattern before large earthquakes.SOFM model is a quite useful tool for statistical properties of earthquakes, for generating huge number of events required to cluster the earthquakes. FigA shows a simple example about the capabilities of SOFM in clustering. The input probability distribution contains continuous structures that are partially interleaved. Clustering by SOFM is based on continuous compact areas, and it thus easily finds the natural cluster boundary.

INTRODUCTION

Statistical properties of earthquakes are studied both by the analysis of real earthquake catalog of Iran and by numerical computer simulations of the Self-organizing neural model in two dimensions.
The study of the past behavior of earthquakes may be extremely valuable to help to predict its future behavior.

Motivated by the above idea, recently a number of techniques for making predictions are to show that neural networks are capable of making short-term predictions of clusters earthquakes location data that are better than the other models.

In application like pattern recognition in seismology, seismic classification, signal and image processing, an important problem is to find doughnut patterns before major earthquakes.

A neural net model with simple adaptation rules for the links between the neurons during the learning process establishes a map of the synthetic earthquake catalog data. During the process Kohonen-Nets establish topological maps [Self-organizing feature maps (SOFMs) originated by Kohonen in 1970's are the unsupervised networks of choice] of the earthquake nets (AllamehZadeh et. al., 2006). Pattern recognition techniques have been applied to show adapted preprocessing in classifying Shape such as doughnut patterns.

This approach gives the empirical relationships among different geophysical and geological features, which are potentially related to the phenomenon of stress release in Tehran region.

The obtained multi-dimensional function has been applied to the calculation of a forecast maximum magnitude field for Tehran region. This preliminary estimate has been formulated on the basis of both the historical seismic catalogue and the structural zonation.

The results are to be considered preliminary. An improvement of such a forecast could be achieved by new data, such as heat flow, depth of Mohorovicic surface, active faults, vertical movement velocities, etc. The strong earthquakes originating at intermediate depths in the Tehran region (located in the center of the Alborz region) are among the most important natural disasters that induce heavy effects (high number of casualties and extensive damage) on the Iranian territory.

The used methodology is quite different from the usual seismotectonic methods that allow delineating seismogenic zones and calculating the seismic hazard inside these zones.

– THE SEISMIC CATALOG OF IRAN AND THE STUDY AREA

In the Alborz region, Gorshkov (2006) define seismogenic nodes prone to earthquakes M>6 and characteristic geomorphological-gelogical features that discriminate seismogenic nodes from non-seismogenic ones. Morphostructural nodes are formed around intersections or junctions of two or several lineaments. The nodes have been obtained by the morphostructural zoning (MZ) method. The compiled MZ map shows the hierarchical block-structure of the Alborz region, the network of boundary zones separating blocks formed at the intersections of boundary zones. The pattern recognition algorithm CORA-3 was defined other nodes capable of such size earthquakes using topographic, morphometric, and morphostructural parameters that describe the nodes. Nodes prone to M>6 exhibit the high topographic contrast and the increased fragmentation of the crust. Results of the work were pointed out the high seismic potential of the Alborz region: this study was identified a number of seismogenic nodes, where the target earthquakes have not yet been recorded.

In order to compare the simulation data the SOFM models with the corresponding data for real earthquakes, we analyze in the following section the seismic catalog of Iran provided by International Institute of Earthquake Engineering and Seismology (IIEES) available at http://www.iiees.ac.ir. The catalog covers earthquakes which occurred in Tehran area during January 1988 to December 2010. As an example, we show in Fig. 1, a seismicity map of Tehran region generated from IIEES catalog, where all large earthquakes of their magnitudes greater than five, which occurred in Tehran area during 1988-2010, are mapped out.

The study area is expanding along the eastern and northern latitude in the Alborz, central Iran, Sanandaj and Sirjan tectonic zones. The tectonic blocks in the studied area along the North West respectively - South East North West South East include. The Talesh with the active tectonic zone that is composed of several NW striking thrust faults. The north thrust fault limits this area from the southwest. The Qezel ozan intramountain basin, as large NW striking syncline (With the Qezel Ozan River in the central) is located in the southwest area of the Talesh. The tarom magmatic arc (The northern mountainous parts of the city of Zanjan) forms the south-western Alborz. In this area, the faults parallel mountain ranges, are more active than other faults and are driven old units on the neocene units. Border zone of the Central Alborz and Central Iran zone passes from the Qazvin, Zanjan and Abhar plains. The southern regions of Tarom Mountains are considered parts of central Iran and Result of NW striking fault performance Tarom Mountains are divided into several tectonic blocks by fault lineaments the most important ones are Basin tectonic subsidence Zanjan - Abhar, to narrow the plain covered with Quaternary alluvial between Zanjan has expanded to Abhar. Soltanieh extraterrestrial, as a thin line mountain northwest - south-east, parallel to the Tarom, through the active fault Soltanieh of Zanjan to stretch and shape Abhar, the more the function of the fault southeast of Tabriz orogenic event is. Mountain Valley ozone subsidence between a gentle synclinal basin of the Cretaceous rocks, Tertiary and younger Brfthay is filled.

Line parallels to the sidelines these desert southwest mountains and in the end zone Soltanieh Urmia - Girl (hills Saeed Abad - Krsf) the zone of Sanandaj - Sirjan Maine Soltanieh and downs along the two zones is located.

Based method classified MZ parts respectively lithosphere includes the mountainous zone, and block Mgablock the lineaments due to a higher category blocks with two blocks of the category below are divided. Block bound by identifying problems such as topography Mountains, between the mountain fronts or within the mountain, plateau and fault length is done. Poured structural lineaments, depending on the characteristics and intensity tectonic movements, linear zone to hundreds of kilometers in length and are within a few kilometers. This value, close ties with the amount of activity and rate of displacement has lineaments. Goroshkov et al (1999) for first-degree separation of lineaments, second and third, respectively, width 10, 5 and 2 km criterion placed.

The morphostructural nodes with high seismicity potential have been identified based on differences severity of tectonic movements (Gorshkov et al, 2003). One of the parameters dependent on intensity tectonic movements is the difference between maximum and minimum topographic height. These lineaments show complete adaptation with the isostatic balance, elastic bending and the horizontal compressive forces in lithosphere (Snyder and Barazangi, 1986).

Topography is usually caused by interaction between successive earthquake occurrences and continuing erosion processes. Hence the location of surface deformation can be caused topographic relief. On the other hand stresses resulting from the topography are significant and can cause seismicity to concentrate in regions of large topographic and or gravity anomalies. Their magnitudes range from a few to hundreds MPa. A topographic contrast of 1500m will cause a differential shear stress in the crust of about 10 MPa, which is roughly the size of the stress drop observed in earthquakes so topographic, isostatic and bugger anomalies are could represent the stress level in upper part of lithosphere so that the difference in topography is equal to 1500 m can cause differences in crust shear stress 10 MPa hence should be studies of seismic activity is considered (Jeffreys, 1976; Dalmayrac et al., 1981). These stresses are of such an order that could be influence the deformation of lithosphere and may trigger large earthquakes.

Isostatic relief is overlaid with topographic relief. Lithospheric thickness or density variations play an important role in creating lithospheric forces (England and McKenzie 1982; Assameur and Mareschal, 1995) and large isostatic anomalies in areas where tectonic forces are active, may exit. Therefore the most important characteristic features in the seismic regime of some seismogenic areas are dominated by elevation So that the most seismic portion of this areas coincide with that where the topographic load is large and or the gravity anomalies have a steep gradient corresponding to large or steep isostatic anomalies (Seeber et al., 1981; Keary and Vine 1996).

One of the parameters related to crust depth heterogeneity is the difference between maximum and minimum Gravity anomalies (relief anomaly), so the lineaments of the characteristics of joined points with minimum distance between the maximum and minimum of distribution of gravity anomalies for instance isostatic anomaly can be suitable index for determining the main border lithosphere blocks with high seismic activity and relative movement (Gorshkov et al., 2003).

Regional bugger anomalies lineaments are identified based on high-pass filter (long wavelength radiation the Earth gravity field). An approximate relation between the depth of density anomaly and the corresponding wave number in the bugger spectrum is given by Featherstone (1997):

$$Zn = R / (n-1)$$

Where, Zn equal depth, n the wave number and R the mean radius of the earth. Accordingly, the deep sited density anomalies contribute towards the long wavelength range of anomalies and subsurface density ones contribute towards the short wavelength part.

By this manner, the structural lineaments were extracted between topographic lineaments that match the sharp changes of isostatic anomalies. The relationship between isostatic anomalies and the distribution of earthquake epicenters was pointed out by many investigators (Dalmayrac and Molnar 1981; England and McKenzie 1982). Differences in crust thickness and density distribution of blocks can lead to stress systems with the potential expansion of faults and seismicity focus on the border of this block (Bott & Dean, 1972).

In this study, tectonic lineaments extracted from maximum gradient of Gravitational, magnetic, isostasy and topographic anomalies (Gorshkov et al., 2003, Jackson and McKenzie, 1984 and Hashemi, 2000) and match them together and also check the satellite images has been done (Figure 3). These characteristics indicate differences in severity of tectonic movements, the degree of disruption and patches classified into heterogeneous lithosphere and depth of crust. Where the lineaments on the active faults are located to cross, causing the seismic nodes are created.

Nogol-Sadat (1978), has divided longitudinal faults and structural lineaments in Iran plateau (that are boundaries of Structural and sedimentary zones) into three main categories: the N striking lineaments (formed in the Late Precambrian and katangai sycle), NE striking (with left-lateral component and Devonian age) and NW striking (left-lateral faults that formed in the Late Precambrian and katangai sycle). In addition, other faults with E-W striking have deformed the Iran plateau. These faults are detectable in topographic relief, magnetic and Gravity anomalies maps (Figure 1).

If the morphological field studies to determine the range of nodes is not done, usually the extent of nodes, with a radius proportional to magnitude earthquakes and seismic activity level in each region are considered. These nodes, those prone to seismic event, with potential for more than 2 SD of each particular area of land are made. Cutoff value of the sector in central and western Alborz, the 5 / 6, Central Iran 3 / 5 and Urmia region - the girl with the 3 / 6 is obtained. Seismic profile important nodes in the study area, is as follows (Figure 1):

Node D1: The Knot, Masouleh fault intersection (North East Valley trout Clan) lineaments cross the border with West and Central Alborz, parallel transverse fault lineaments Lahijan and are Rudbar. Masouleh two large fault blocks with different heights and includes a central Azimuth Bqrq cool mountain) north north-east (and Mountain Grape) southwest (making separate. Lineaments cross the fault line NNW more effort because South West Alborz separation tectonic structures in the direction of the Eastern Highlands - West with the exchange right is the central Alborz.

The lineaments, causing separation Embayment Plains Zanjan, Qazvin south of the basin, the southern part is more. Distribution of magnetic intensity at this node, indicated maximum changes in magnetic lineaments along NE direction and the transverse fault is Masouleh. The quake occurred 31 Khordad 69 and its aftershocks at this important node seismicity bring it to prove.

Node D2: The node is located in south Boein Zahra and longitudinal lineaments intersection Soltanieh - South hillock, Aypk fault, faults and lineaments of southern hillock Rastahay NE and NW with a cross is. Figure 3 shows the drastic changes in magnetic intensity is the location of this node. Historical earthquakes within this node include:

- an earthquake in the third millennium BC in the border zone between the plains and the Soltanieh Qazvin (° 6/35- ° 9 / 49).
- The December 10 quake in the year 1119 with a magnitude 5 / 6 in the Qazvin Plain (° 7/35- ° 9 / 49).
- October 20, 1876 AD earthquake with magnitude 7 / 5 on the border between the lowland plain of Qazvin and Zanjan (° 8/35- ° 8 / 49).

Node D14: The nodes in the north and the confluence of Razan Pavilion Nosrat fault, the border blocks of Central Iran Sanandaj Vphnh - Sirjan NE lineaments cross the line is located.

D3 and D4: these nodes, the confluence of the transverse lineaments of the Strike on the NE and NW faults are trying to cause obvious changes in the magnetic intensity of the line said. Such a situation, the node fault D6 in South more effort can be seen with the difference that, unlike the two nodes before this node, with no history or history is an important device. So probably quiecence conditions on the ruling.

D15 and D16: the nodes along the confluence of lineaments with NE and NW, along the fault Sngavr, is.

Node D20: This node is located in East Mahneshan confluence of magnetic lineaments along NE, faults and lineaments Soltanieh Vgsl Zanjan North - South Sngavr - Zarin Abad is. This node also meet seismic behavior is stillness.

Node D17: The nodes in the Middle East city of confluence Sngavr fault and the fault is located Masouleh rest seismic behavior shows.

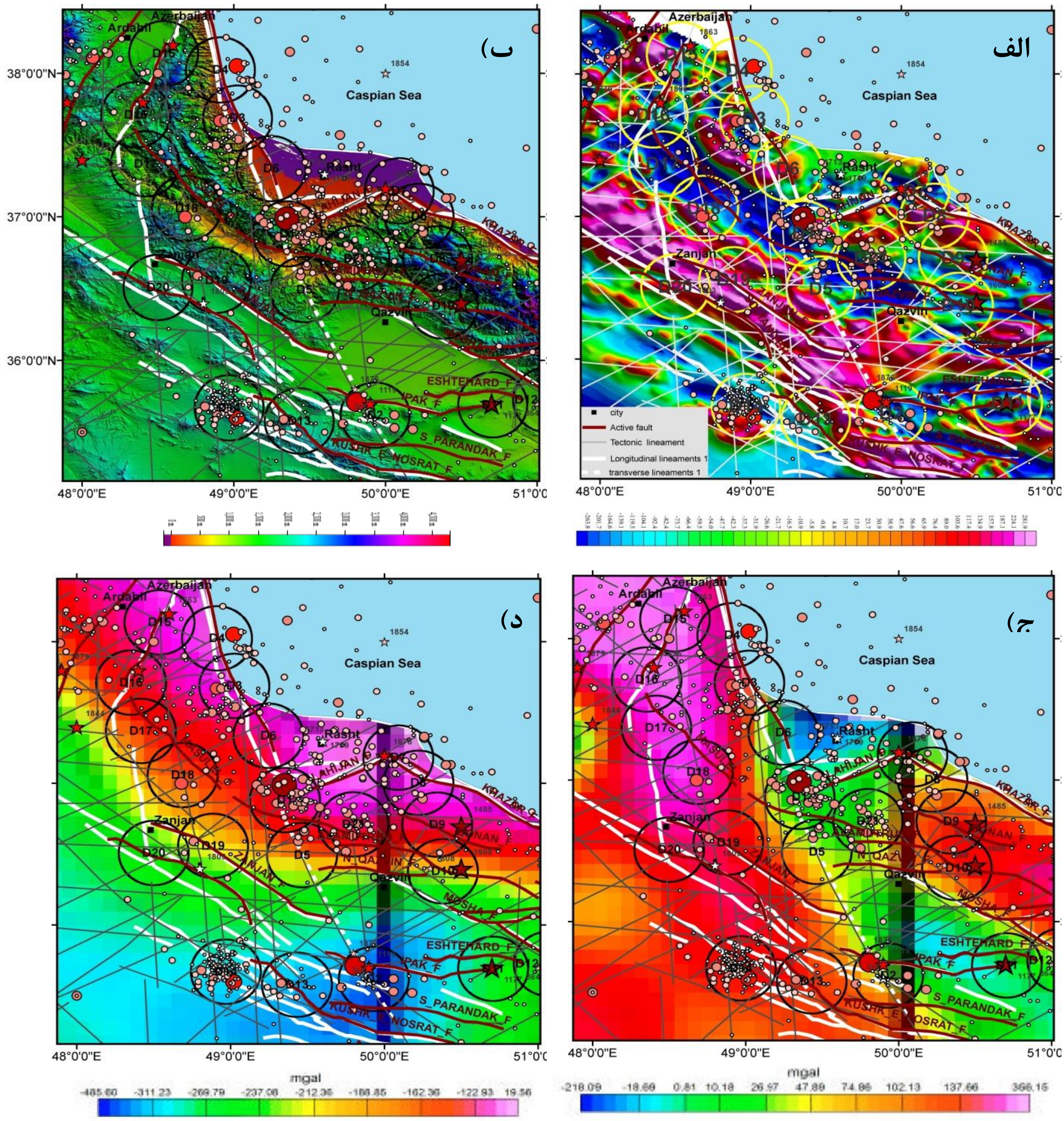

Figure 1. A - Extraction of lineaments in the distribution map of magnetic anomalies (digital images taken from aerial magnetic provincial geoscience database.) Lineaments have been drawn, for sure, with layers of digital topographic lineaments, has been compared to B - Topographic maps. Topographic distribution, based on Landsat Tm images using software Global Mapper, is obtained. C - Gravity anomaly map of the distribution amounts Bvgr area (Siddiqui et al, 2008), D - Map the distribution of abnormalities Ayzvstazy Zhyvptansyl EGM96 model and topographic effects withdrawal δg2, is obtained (Siddiqui et al, 2008). Layer draws the lineaments of digital topographic lineaments and magnetic anomalies based on the rapid changes and Gravitational Ayzvstazy Bvgr.

– STATISTICAL PROPERTIES OF EARTHQUAKES

In this section, we show the results of our numerical simulations of the machine learning algorithms, and compare them with the results of our analysis of the seismogenic node in our catalog in the region.
Since the early 50s, Neural Network architectures and algorithms have largely evolved, from simple structures.

We study several observables, i.e., (i) the magnitude distribution, (ii) the local recurrence-time distribution, magnitude distribution before and after the mainshocks.

– THE NUMERICAL SIMULATION

SOFM model is a quite useful tool for statistical properties of earthquakes, for generating huge number of events required to cluster the earthquakes. Fig… shows a simple example about the capabilities of SOFM in clustering. The input probability distribution contains continuous structures that are partially interleaved. Clustering by SOFM is based on continuous compact areas, and it thus easily finds the natural cluster boundary.

DISCUSSION & CONCLUSIONS

Spatial and short-term forecasting large earthquakes (about a few months), are important issues Seismology. An example of work done in this direction by (Gvrvshkvf et al, 2003) is presented. This method for identifying structural instability, land zoning method of structural shape or MZ tool is used effectively to determine the structure of block faulting earthquake prone areas are. This rise in many parts of the world's earthquake has been tested and results by the occurrence of extreme events in areas that had been studied before is confirmed. So that 84% of seismic events occurred.

After determining the nodes in the Alborz Bank with the above method, the neural network to determine the approximate time Khvdsazmandh next event and compare the relative level of tectonic activity nodes have been used and also in the scope of any single pattern recognition method (Pattern Recognition) were assessed (Figure 5). Given the variety of structures in the ground undermines the wave and make random and uncertain nature of seismic signals are, so to identify the pattern of seismic signals should not form a system hit.

Superiority of these methods is based reasoning are approximate. First, neural networks as an intelligent system for the non-algorithmic work by providing examples solved able to achieve a response method to obtain approximate. So recognition method according to the desired data are optimized Secondly, massive parallel processing, and connections to the extremely high performance computing leads. Thirdly, non-linear processing capabilities of their flexibility and accuracy than conventional methods makes different.

Using the above method, in addition to identifying high risk areas, the ideas can be diagnosed more likely locations for events and providing land worth in regard to the diagnosis of seismicity patterns, we can approximate time of the earthquake in the next few months also determined. Usually before a large earthquake, seismicity region will suffer confusion, so that small earthquake a few months ago, in the desired area, the epicenter they occur, seem completely random and any particular pattern and the law does not comply. Spatial prediction of these earthquakes was complicated, there are the chaotic order and obey certain rules so that their pattern recognition using advanced statistical methods today, is possible.

Mathematical algorithms for seismic pattern recognition ago markers has been suggested that this capability complicated rules system can be used to detect earthquakes catalogs and place the next big earthquake in the next few months estimated. These models are intended to identify the location of clusters and their distances from each other (Donat seismic detection) are approximate solutions to the areas by seismic generator offer (Magee, 1969). Doughnets location patterns, according of figures (5 A - D), causing the range seismogenic node specified.

Following procedures according to the zoning status of land values collapsed structure and distribution of magnetic intensity, and Ayzvstazy Gravitational area, as trends are Nvan potential risk of occurrence of earthquakes larger than 2 SD introduced:

-D4-D2 transverse lineaments the border of central and western Alborz
-D4-D16 transverse lineaments in western Alborz, with NE strike.
-D3-D17 transverse lineaments in western Alborz, with NE strike.
-D6-D18 transverse lineaments in western Alborz, with NE strike.
-D14-D15 lineaments in western Alborz, with the North – South strike.

Above the intersection along with each other and also with the active fault zone, seismic generator nodes are created. Considering catalog and historical and instrumental earthquakes with known magnitude, all recorded earthquakes with magnitude over 6, has occurred at the intersections in this direction.

Clustering using artificial neural networks in the western Alborz, to identify high-risk seismic zones, causing identifying several points in seismogenic nodes D14, D18, D2 and D1, respectively, located 30 km west of Aavaj, Drama Village, 20 km south of Boin zahra and 30 km south east of Fuman (see Table 4), as parts of in these areas has been future seismic risk.

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