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Using Nonlinear Image Processing Techniques for Realizing Seismogenic Lineaments in Northern Regions of Iran

Reza Mehrnia, PNU, Qazvin, Iran
r_mehrniya@pnu.ac.ir

Abstract

ETM based photomaps, which of spectral signatures have been acquired by Landsat7 technologies, may contain a large amount of information critical for realizing seismogenic lineaments. False color composite of spaceborne images however are not ready to use dataset for determining lineaments as the main fabrics related to hazardous regions only if the different quantities of the digital numbers have been clearly analyzed by professional statistics. As a rule, current seismic resources have some physical effects straight on the crustal dynamical formation may be occurred by oriented strains along seismic fault systems. In this research, fractal filtering techniques have been used to realize the coherent signatures of remotely sensed structures by means of nonlinear relationships. Magnitude - Area equation and the power-spectra relations are two types of mathematical expressions for analyzing of electromagnetic signatures using multidisciplinary approaches. According to the earthquake catalogues, a few cross cutting structures are playing the main roles for generating seismic potentials in active fault regions. Therefore, nonlinear analysis of those remotely sensed data which contains of the temporal and Fourier transformed quantities, give rise to useful series of self similar spectra for resolving the complexities of the epicenters and adjacent lineaments. Slope-based discrimination between self-similar populations is an essential approaching toward fractal filtering techniques. As a result, several decomposed lineaments with meaningful seismic potentials could be realized by frequency enhancement processes for better understanding of the earthquake patterns in Alamoot Sofla region as a part of the great seismogenic zones in north of Iran.

Key words: Earthquake, Fractals, Image processing, Lineaments, Nonlinear techniques.

1. Introduction

An ETM photomap normally is constructed from a set of electromagnetic signatures detected by thematic scanners installed on Landsat7 satellite. Respect to seismogenic lineaments, multispectral images usually are used to finding decomposed fabrics around active structures after recognizing anomalous reflections from background and threshold populations statistically. A seismogenic lineament that is derived from remotely sensed images can, however, be completely understood and then serves to seismic potentials only after its raw data have been processed properly. Therefore it is necessary to extract and classify the unique self affined properties of DN values for modeling purposes based on GIS techniques.

Frequency analysis is the basic method used to process ETM images for realizing coherent fabrics related to seismogenic environments. Box-plot algorithms are extensively used by professional image processing techniques for separating active – non active lineaments in

most of cases (Turcotte, 1996). Fractal filtering technique is a recently-developed approaching to extract frequential resources from electromagnetic signatures (Prince, 1991). The basic assumption for this method is that an image generated by specific methods may be processed in terms of self similar appearances as the basic properties of the nature. In this paper the filters are defined on the basis of the power law functions in which there are several similarities of scale invariant DN values nearby seismogenic resources. This type of filters are generated in Fourier space by applying the simple concentration-area (C-A) relations into the power spectra functions (Cheng et al., 2000). Therefore, the frequency images can be used to realizing the lineaments may be related to anomalous signatures of historical earthquakes. The frequency filtering techniques are popular for signal processing in geophysics. Signals in spatial domain are considered as superimposed data with various wavelengths. Two dimensional signals in spatial domain can be readily transformed into the frequency domain by means of Fourier Transform (FT) functions, which gives a pair of maps containing the real and imaginary components of spectrums.
In regional scales, Eq.1 is initiated a filtering technique for dividing the subsets from an electromagnetic reflection through seeking breaks on the plot of ln [E(r)] versus r/2π:

$$r = (wx2 + wy2)^{1/2} \quad (1)$$

Also the self-similarity nature could be characterized by a power-law distribution in which its power spectrum (E) is proportional to a power (α) of spatial frequency (f) using Eq.2:

$$E\ (f) \propto f^{-\alpha} \quad (2)$$

where π is called isotropic scaling exponent and f equivalent to the r/2π.

Because of the imagery anisotropic natures, linear filters are not suitable for processing electromagnetic signatures. Hence it is not recommended for realizing decomposed lineaments which are usually hidden and controlled by seismic fault systems (Mehrnia, 2006).
Anisotropic properties of satellite images are often reflected in 2-D power spectrum. This anisotropy can be characterized by using a proper method based on power spectra distributions (Cheng et al. 2000). The relationship between the 'area', [A (CE)], on the power spectrum plane with power spectrum slopes above threshold (-β) and the power spectrum (E) may show power-law relationships. Spectral equation is expressed by Cheng (2000) as Eq.3:

$$[A(CE)] \propto E^{-\beta} \quad (3)$$

Estimating dimensions (E) by the values of log A(CE) vs. log E is a useful method for planning various ranges of E, based on which filters can be constructed. This method is named S-A method (Turcotte, 1996). In practice the filters generated by Eq.3 in Fourier space can retain the anisotropy of raster data with the identical scaling properties and power spectrum respects. The extracted DN values with distinct fractal properties and anisotropic natures can be obtained in spatial domain by the Inverse Fourier Transform (IFT) with the filters applied.
The implementation of the fractal filtering method for statistical image processing purposes consists of the following steps;

-Transform DN values from space to frequency domain using FT functions.
-Introduce to power spectrum relationships for frequency DN values.
-Apply S-A plot to the obtained power spectrum.
-Satisfy to extreme slope variations (yield points) as the filter values within binary grids.
-Multiply the filters to the real and imaginary FT maps respectively.
-Transform the filtered grid maps back into the spatial domain during IFT technique.

2. Data and Material

An integrated aeromagnetic data (GSI,1995) plus Multispectral ETM dataset (NGDIR, 2003) was selected for determining lithological units and structural patterns as shown in figure 1.

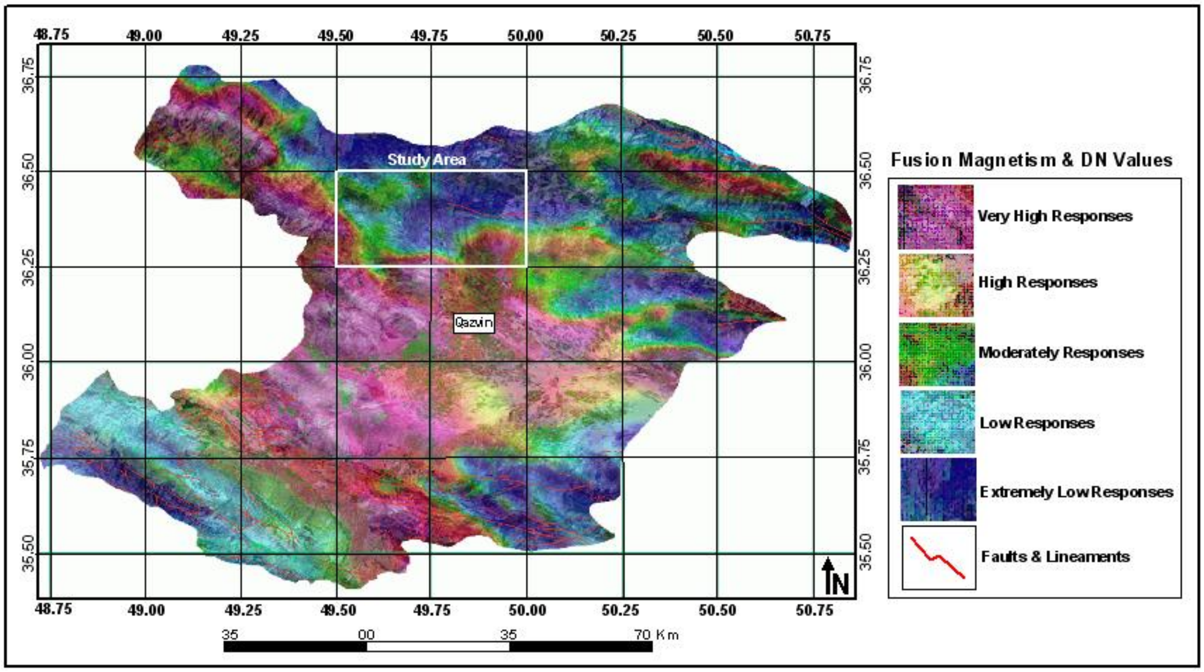

Fig 1: Superimposed photomap: ETM plus Aeromagnetic dataset, Qazvin province.

In this figure, very high responses of the fused signatures indicate to igneous rocks with intermediate to basic compositions (such as Trachyandesite and Monzodiorite). High responses also indicate to intermediate magmatic extrusions which are usually affected by alteration or weathering processes. Moderately responses of the signatures are dominantly recognized as transitional zones between high - low values and contained structural patterns such as faults, rings and folded regions within quaternary sediments. Low values and extremely low values of the fusion signatures may indicate to sedimentary formations with low magnetism responses and high values of reflected DNs.

In practice (field checking results), red colors indicate to high responses magnetization of igneous units which may be lighted to yellowish as the remotely sensed moderate signatures in crushed zones (gouging area with several alteration features). Bright greens to light blue colors indicate to young alluviums with low responses of magnetization and dark blue reflections indicate to metasediments contain very low responses of DN and magnetism.

Historical earthquakes have been extracted from catalogue (IIEES, 2011) and interpolated by Inverse Distance Weighting (IDW) techniques as shown in Fig.2:

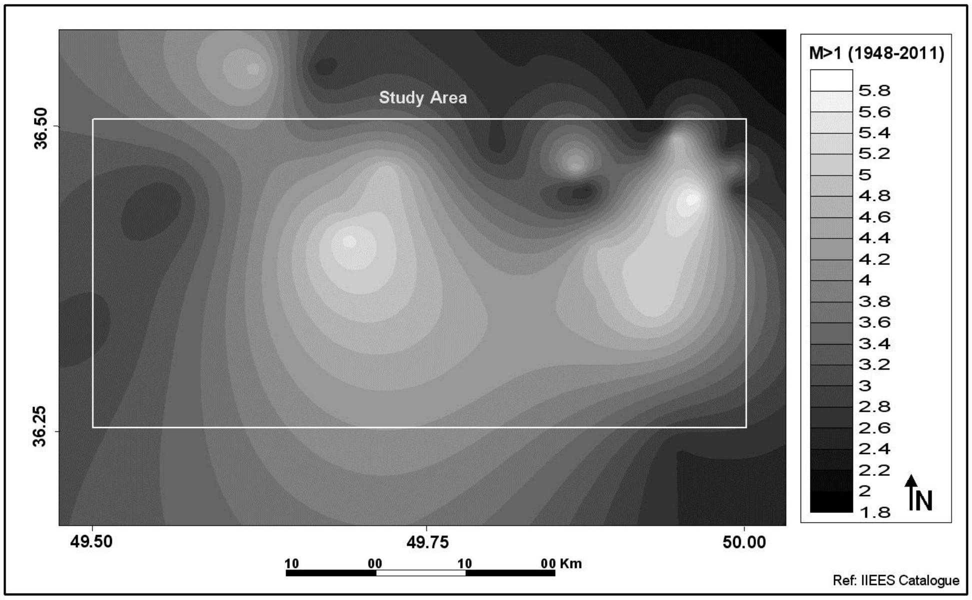

Fig 2: IDW interpolation result for Alamoot Sofla region (magnitude ≥ 1.5, 1948 - 2011)

According to IIEES catalogue,(1948- 2011), two main seismic events have been occurred in Alamoot Sofla region. The first epicenter is located in 49.70 of longitude and 36.40 of latitude approximately. The second also is located in 49.95 of longitude and 36.45 of latitude approximately. Concerning to geophysical fusion map (See Fig.1), most of epicenters can be correlated with moderate to low responses of remotely sensed signatures.

3. Analyses and Approaches

Comparing DN values with seismic epicenters (See Fig.2), provide a limited domain of signatures related to historical earthquakes. As a result, the same interpolation could change discontinuous DN into continuous dataset as shown inFig.3.a. The generated IDW map also could be converted to the frequency signatures by means of Fourier Transformation (FT) technique in Fig.3.b.
In Fig.3.a, Spatio-Temporal variations imply to DN=120-190 for seismic activities of Alamoot region; while inFig.3.b, Frequential variations differently imply to more limited (restricted) area than ordinary DNs for locating earthquake epicenters.

From geomatical points of view, high responses of frequency signatures belong to the most important coherent values of electromagnetic reflections. Also low frequencies indicate to incoherency of the signatures with no priorities for seismogenic environments. Interpolating of the frequency signatures (both significant and traces), generate a power law relationship (S-A) between the values of contours and the areas enclosed by the contours as shown in Fig.4 (Mehrnia, 2009):

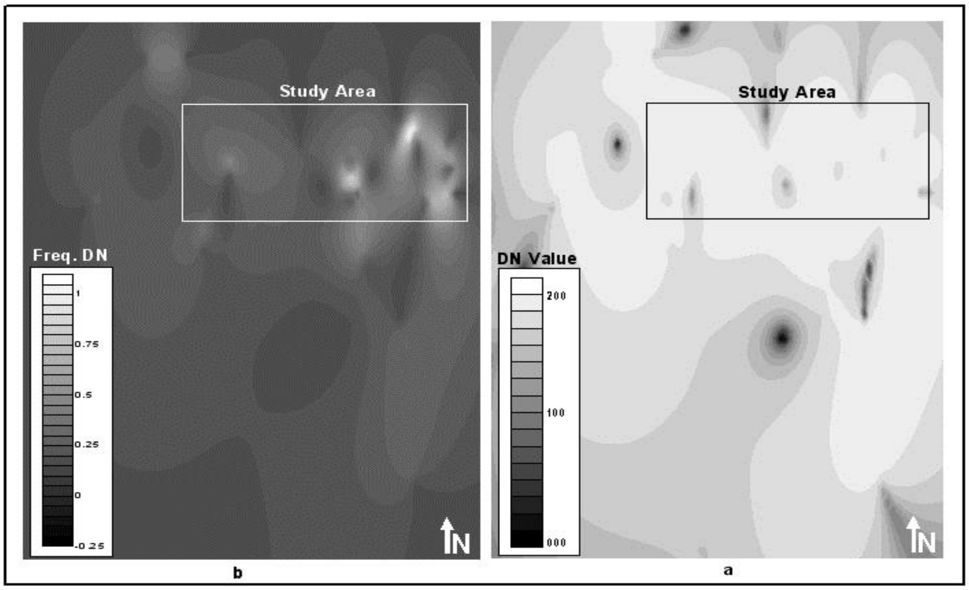

Fig 3: Temporal (a) and Frequential (b) interpolation results for DN values- Alamoot Sofla

Fig 4: Log-log plot showing DN values vs. area of spectrum- Alamoot Sofla

Selected filter value (1.275 on Fig.4)) is usually calculated as the biggest meaningful slope variation within fractal populations (Cheng et al, 2000). Applying the filter to transformed DN-values (See Fig.3.b) and converting frequency values back to the spatial domain (IFT), generate a new perspective of seismogenic resources (and lineament) in Fig.5:

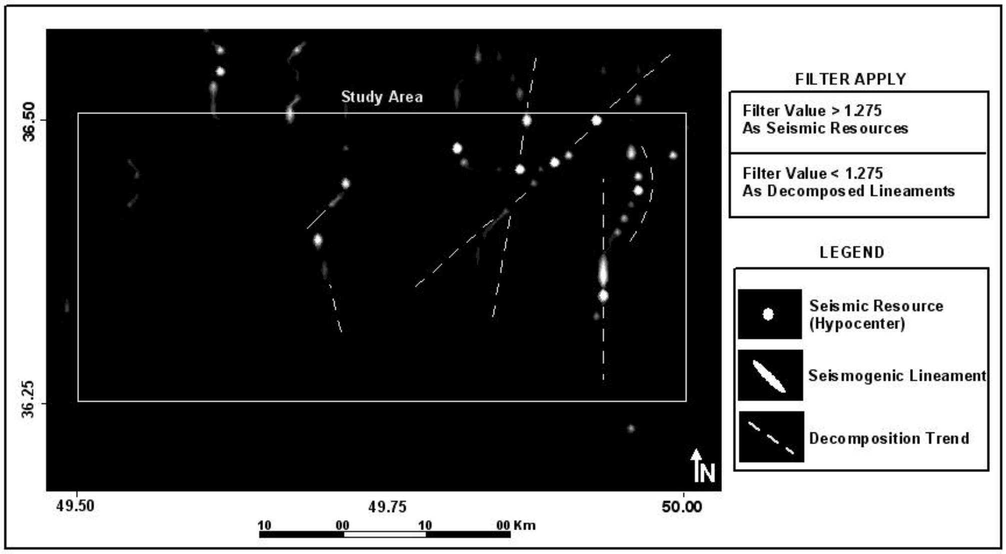

Fig 5: Coherent (white points) vs. Incoherent (black grounds) distribution of DN values for Seismogenic lineaments in Alamoot Sofla region (North of Iran)

The binary filter represents to relatively high and low frequency power-spectra without regularly bounds in Fig.5. Dark black background is a converted grid map using IFT technique with filter area < 1.275 applied. And the white points are a converted map using same method, with filter area > 2.127 applied. The one with the lower power-spectrum filter applied; will represent to background DN values as stable regions; Whereas the filter area with the higher power-spectrum value represent to anomalous DNs which cause to appearing seismogenic decomposed lineaments in Alamoot Sofla region. This type of spectrum-area plots can separate two distinct groups of self-similarities with different governance power-law relations.

4. Conclusions

The fractal filtering technique is an effective method for realizing seismogenic decomposed lineaments by using the concept of coherent component peculiarities associate with ETM photomap reflections. Applying spectral models to geophysical dataset is a common technique represented by Cheng et al (2000), however using the S-A plot for populating remotely sensed signatures of active fault zones (such as linear traces, aggregated features and decomposed trends) is completely private to this research. Frequency related DN values obtained using filters, cause to generating new sets of threshold and anomalous reflections which represent to one or several seismogenic hypocenters may control the seismic behaviors of the active fault systems. This research has shown that hypocenters and frequently relevant lineaments in Alamoot Sofla region could be recognized by nonlinear techniques (See Fig.5). Most of these hidden structures have two major directions; the first is in the N-S and direction while the second is usually followed by NE-SW trends. Lineaments and coherent resources (See the white points on Fig.5) are two identified features that seem to have enough potential for future seismic events in Alamoot Sofla region. Therefore, coherent features as the main hidden structures related to historical earthquakes should be studied as well as observed fault systems for locating next destructive earthquake and its hazardous region precisely

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