GEO-LINEAMENT CHARACTERIZATION USING WAVELET APPROACH: A CASE STUDY IN THE UISEUNG CALDERA REGION

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ABSTRACT: Wavelet approach is regarded as a useful methodology for geo-environment analysis with respect to spatial objects with periodicity and spatial pattern, compared to autocorrelation analysis, Fourier analysis, variogram analysis and so on. However, there are a few case studies for geo-lineament characterization with the actual geo-based information such as remotely sensed imagery and DEM. In this study, wavelet approach in the Uiseung caldera region are carried out to delineate characterization for geo-lineament spatial pattern. There are high possibilities of the development of radial lineaments from the centre of round crater due to the eruption of a volcano and the subsidence of a crater. We have grasped the directionality of the whole linear structures of the caldera via rose diagram, and then performed wavelet analysis on the profiles of orthogonal directions for main directions of the lineaments. The result of this study is likely to be used as a fundamental data in order to grasp the outline of caldera structure prior to the close estimation

KEYWORLDS: geo-lineament, DEM, wavelet analysis, GDPA algorithm, rose diagram

1. INTRODUCTION

Lineaments are defined as straight linear elements visible at the Earth's surface and which are the representations of geological and/or geo-morphological phenomena (Clark and Wilson, 1994). The lineaments represent topography like soft ground range and layer boundary formed by erosions, faults, and folds. So its feature is very important to data analysis about geological survey, mineral and groundwater survey, and interpretation of geologic structure (Masuoka et al, 1988; Sabins, 1997; Lee and Chi, 1995). But previous studies mainly have focused on extraction of lineaments, so more studies are not sufficient at present.

The objectives of this study are to extract geo-lineaments and furthermore analyze it by using wavelet transform and lastly grasp the whole structure of caldera. The study area is a part of caldera structures in Uiseung, Korea and two maps are used; DEM and geological map. Geo-lineaments are obtained from two maps and rose diagram shows the main directions of lineaments. Then wavelet analysis is performed on the profiles of orthogonal directions for main directions of lineaments.

2. GEOLOGY

The Gyeongsang Basin is a non-marine sedimentary basin formed in the southeastern part of Korea during Early Cretaceous time. Based on volcanism and plutonism, the Cretaceous rocks in the Gyeongsang Basin are divided into the Sindong, Hayang, Yucheon groups and the Bulguksa Intrusive Rocks (Chang, 1975).

Figure 1 is the geologic map of this study area and contain Hayang, Yucheon, and Bulguksa Intrusive Rocks.

Hayang groups are dominantly sedimentary rocks that rarely intercalated with volcanics, but Yucheon Group consists mainly of calc-alkaline volcanic rocks; these are showed center of this study area. These groups are extensively intruded by the Late Cretaceous granitoids (Choi, 2006).

As geo-lineaments, there are NW-SE strike-slip faults and ring-shaped and linear normal faults caused by caldera (Kim et al, 1996).

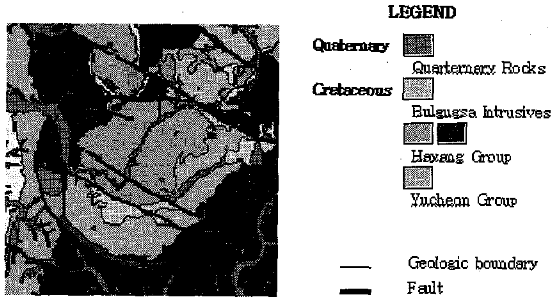


Figure 1. The geologic map of the study area.

3. METHODOLOGY

3. 1. Gradient Direction Profile Analysis

The GDPA algorithm was initially proposed by Wang (1992) and has been applied for road extraction from high-resolution remotely sensed data and air-photo image. The main idea of the GDPA is to fit a profile crossing a line using a polynomial function and to find the point where the function reaches its extreme value.

The first step for GDPA algorithm is calculating the maximum gradient direction for each pixel and defining the gradient direction profile for a given pixel along the maximum gradient direction. Subsequently, we determine a polynomial function to fit the gradient profile using the least square method. The fitting function is

$$f(x)=b_0+b_1.x+b_2.x^2 \qquad (1)$$

To find the top or bottom of the profile, we compute the derivatives of Eq.(1) and to reduce noise for line network extraction, we consider the curvature of the curves. The curvature is defined as

$$K(x)= |f''(x)| / (1+f'(x))^{3/2} \qquad (2)$$

Only when the curvature near the extreme value point is great enough GDPA will accept this point as part of the lines to be extracted.

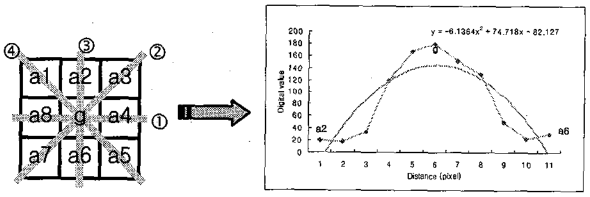


Figure 2. Basic concept of GDPA Algorithm.

3. 2. Discrete wavelet transform

The discrete wavelet transform (DWT) is known to one of the most useful techniques for multi - resolution image analysis. Furthermore, the wavelet scheme composed of the wavelet transformation and its inverse transformation provides a powerful and flexible set of tools for handling problems in noise removal, signal or image compression, object detection, image enhancement and so on (Mallat, 1989).

DWT transforms a discrete time signal to a discrete wavelet representation. It converts an input series x_0, x_1, $..x_m$, into one high-pass wavelet coefficient series and one low-pass wavelet coefficient series (of length n/2 each) given by:

$$H_i = \sum_{m=0}^{k-1} x_{2i-m} \cdot s_m(z) \qquad (3)$$

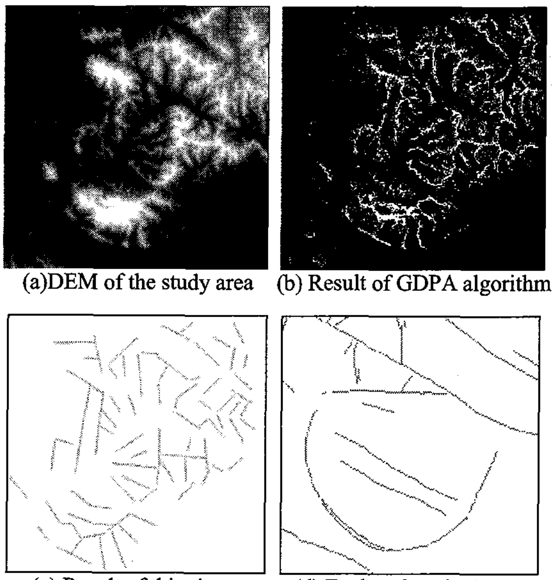
$$L_i = \sum_{m=0}^{k-1} x_{2i-m} \cdot t_m(z) \qquad (4)$$

where $s_m(z)$ and $t_m(z)$ are called wavelet filters, K is the length of the filter, and i=0, ..., [n/2]-1.

In the DWT transform, a down-sampling algorithm is used to perform the transformation. Therefore, the whole length of the function will reduce by half after the transformation. This process continues until the length of the function becomes one.

In this study, we extracted lineaments from DEM using GDPA algorithm and retouched to simple vectors manually. Then we draw rose diagram using lineaments, which extract from DEM and the fault lines of geological map. From the main directions as a result of rose diagram, we determined the orthogonal line and perform wavelet analysis on it.

4. RESULTS AND DISCUSSION



(a)DEM of the study area (b) Result of GDPA algorithm

(c) Result of thinning (d) Faults of geologic map

Figure 3. The geo-lineaments of DEM and geologic map.

We applied GDPA algorithm to DEM(Figure 3(a)) and got Figure 3(b) as a result of it. Then, Figure 3(c) was made to simple vectors manually after thinning. Figure 3(d) shows fault lines in the study area and this is from the geological map.

To know main directions of lineaments of the study area, we merged Figure 3(c) and 3(d) into one file and drew rose diagram of using it. From Figure 4, it is revealed that N140~160°W are the directions of high frequency and the main direction of the study area is NW-SE.

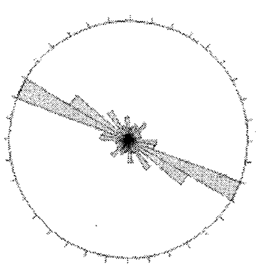


Figure 4. The rose diagram of DEM.

By using this, we determined the direction of orthogonal line; this direction is NE-SW and performed wavelet analysis on it. Figure 5 shows the result.

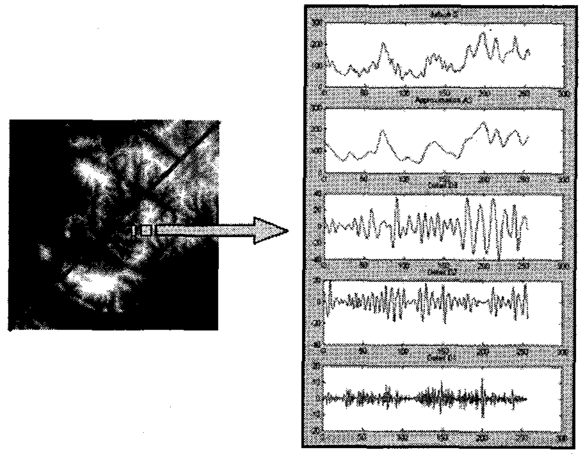


Figure 5. Results of wavelet transform.

In survey, to determine where to investigate is very important. So investigators usually determine study area that has huge change and feature of the area. Caldera boundary will be very important in caldera survey.

As you know, you can find high area somewhat in DEM, but it's hard to identify correct boundary using DEM. However, if you use wavelet transform, the results will change.

Figure 5 is the result using wavelet function 'db4' and level 3. Y-axis of the first graph show pixel value of orthogonal line and x-axis is location of the same line. So we could get the cross section of orthogonal line. Using this, you can aware of caldera boundary and inner shape of caldera because it shows height of caldera correctly.

The study area is Hwasan caldera in Uiseong, Korea. Compared DEM with wavelet analysis, we become aware that caldera locates center of the geologic map (Figure 1) and center of inner caldera slightly soars. Besides we know that Southwest of caldera boundary is more obvious and higher than Northeast of it. The second graph of wavelet analysis shows huge feature of orthogonal line and third to fifth graphs show the small-scale elements of orthogonal line as a result of more detailed analysis. So the result combined second to fifth graphs is the first graph. Like this, wavelet transform offers both summary data and detailed data.

5. CONCLUSION

In this study, we identified the whole structure of caldera using wavelet transform.

At first, we extracted lineaments from DEM using GDPA algorithm and got fault lines from geologic map. By using rose diagram, we investigated the main directions of lineaments and could know the direction is NW-SE. So we performed wavelet analysis on the orthogonal direction for the main direction, NE-SW. As a result, compared with DEM, wavelet analysis showed caldera boundary and location and the whole structure of caldera.

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