Automated Lineament Extraction and Edge Linking Using Mask Processing and Hough Transform.

Sungwon Choi*, Jin-Soo Shin*, Kwang-Hoon Chi**, Chil-Sup So*

*Department of Earth and Environmental Sciences, Korea University
Seoul 136-701, Korea
**Korea Institute of Geology, Mining and Materials(KIGAM)
Earth & Environmental Division
Taejon 305-350, Korea

In geology, lineament features have been used to identify geological events, and many of scientists have been developed the algorithm that can be applied with the computer to recognize the lineaments. We choose several edge detection filter, line detection filters and Hough transform to detect an edge, line, and to vectorize the extracted lineament features, respectively. Firstly the edge detection filter using a first-order derivative is applied to the original image. In this step, rough lineament image is created. Secondly, line detection filter is used to refine the previous image for further processing, where the wrong detected lines are, to some extents, excluded by using the variance of the pixel values that is composed of each line. Thirdly, the thinning process is carried out to control the thickness of the line. At last, we use the Hough transform to convert the raster image to the vector one. A Landsat image is selected to extract lineament features. The result shows the lineament well regardless of directions. However, the degree of extraction of linear feature depends on the values of parameters and patterns of filters, therefore the development of new filter and the reduction of the number of parameter are required for the further study.

INTRODUCTION

Lineament is a linear topographic feature of regional extent that is believed to reflect crustal structure (Robert and Julia, 1987) and recognized on aerial photos, satellite imagery, or topographic maps (Ben and Stephen, 1997). It has been processed and utilized as primary or secondary element in mineral exploration and other geological application. However, if human extracts this lineament, personal experiences have an influence on the result. Also, it' s a time-consuming work. The objective in this study is to develop algorithm of automated lineament extraction which need less human aids and time. The processing in the lineament extraction is largely divided into two steps. The first is to enhance an image so as to make linear components distinct, and the second is to vectorize the image. There are usually two methods in the image enhancement; Filter and Segment Trace Algorithm (STA) (Koike *et al.*, 1995). The former is to detect a boundary between shaded area and light area using edge filter. However, this method accentuates the line that is perpendicular to sun' s azimuth angle, because linear feature that is parallel with sun' s azimuth angle is a lower digital number. The latter uses variance of each direction in sub window. This method aims at a mountainous area, not an alluvial plain area. Recently, Dynamic Segment Trace Algorithm (DSTA) was introduced for a special processing step for a river system by Won *et al.,* 1998. In vectorization step, usually referred to as edge linking, we apply the Hough Transform to the image in order to link points and make straight lines. There are many implementations of the Hough Transform. In this study, we utilize two arrays to keep track of the original coordinates of the pixels in Hough Space, and for accumulator cells.

MASK PROCESSING

Band 4 of Landsat Thematic Mapper (114/35), obtained on November 4,1995 was used for the study. Sun elevation in this image is 31° and sun azimuth is 144°NE (Fig. 1).

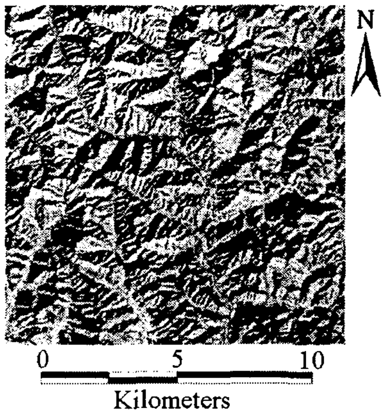


Fig. 1. Test image (400x400 Pixels)

Edge detection filter was used to extract linear components in this study. There are two fundamental methods for using edge detection filter. One is a first order derivative edge detection and the other is a second order derivative edge detection. First order derivative edge detection utilizes a set of mask, where each mask has its own orientation at regular intervals. Second order derivative edge detection uses one mask of spatial second order differentiation to accentuate edges. Several edge detection filters were tested in this study to improve linear components and then, line detection filters were selected and applied to the edge detection filtered image.

edge detection

We tested numerous edge detection filters to detect linear feature. However, with second order derivative edge detection filter, such as Laplacian and various sized Mexican hat masks, the result emphasized extremely linear feature that has a perpendicular direction of sun azimuth angle, while the first order derivative edge detection filters showed unbiased linear features.

In this study, we selected and applied a first order derivative edge detection filter; Nevatia-Babu template gradient impulse response arrays with 5x5 masks in 30 degree increments (Nevatia and Babu, 1980). Because masks of higher size can be more sensitive to edge orientation, the filter produced more unaltered and cleaner linear feature than 3x3 masks (Fig. 2).

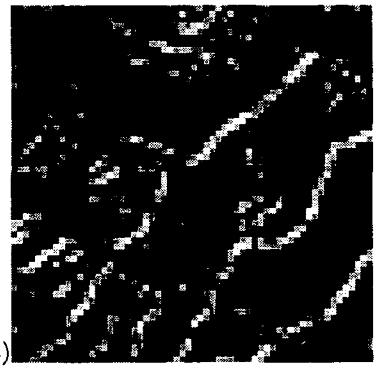
(a)  (b) 

Fig. 2. (a) Nevatia-Babu filtered image. (b) Sobel filtered image.

As shown in Fig. 2, linear components were appeared, regardless of directions. However, linear features in perpendicular direction to sun azimuth angle consist of a higher Digital Number (DN) than in other direction. That problem can be solved with using line detection filter.

line detection

Various line detection filter were tested and selected to find a linear feature of higher DN than circumference in the edge filtered image. Line detection filter is a set of mask that has a high pass filter shaped profile. Each mask in the set is used for detection of linear component at the corresponding direction (Fig. 3).

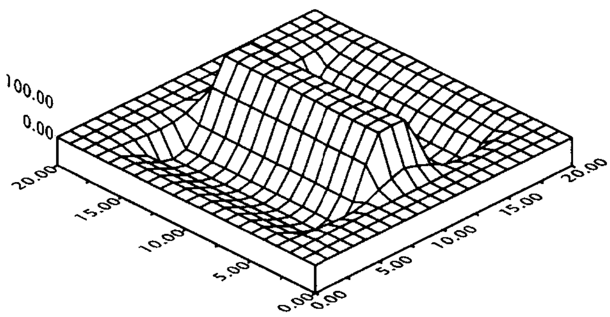


Fig. 3 3D visualized mask. Each mask represents its own direction.

Because positive portion of the line detection mask is considered as a linear feature, this portion in sub-image was selected with linear component, where the sub area of the original image which the mask covers is called the sub-image in this paper. However, if all positive portion of the mask would be accepted, the detected linear component could be too thick and two lines might be merged into one. To solve that problem, weight factor was used in the study to make linear components thin. A weight factor applied to a cell in a mask, was computed with a maximum value of the mask and the cell value. The equation is given by

$$f(x_i) = \frac{i_{th}\ value\ in\ Mask}{Maximum\ Value\ in\ Mask}$$

, where i range from 1 to the number of positive value in mask. If the weight factor is higher than 0.9 and result value through line detection filter is higher than threshold value (g_max), this linear feature is linear component (Fig. 4A and Fig. 4B).

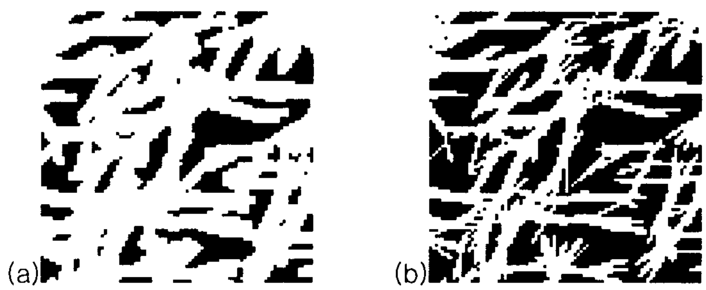


Fig 4. (a) Weight factor is bigger than 0. (b) Weight factor is bigger than 0.9

However, if the variance of DNs on the linear feature in sub-image of edge detection filtered image is higher than a given threshold value (var_min), the linear feature can be accepted as a peak. Therefore, in this case, we removed linear feature from linear component (Fig. 5).

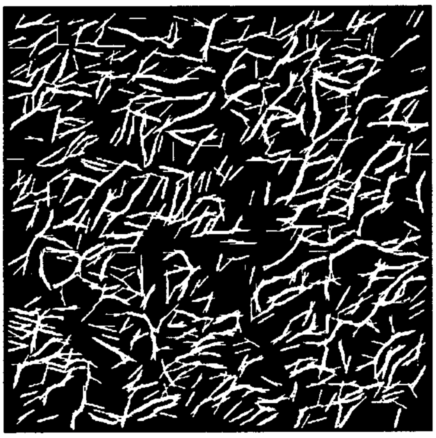


Fig. 5. line detected image. (g_max=27, var_min=26)

Variance image

In edge detection filtered image, a slope has a irregular surface, whereas, a large valley or ridge has a regular surface. These features can be found in a variance image with DNs in sub-image. We computed an average by using a 5x5 average mask and then, calculated a variance in the sub-image. The variance image was converted into a negative to detect a valley or ridge using line detection filter (Fig. 6).

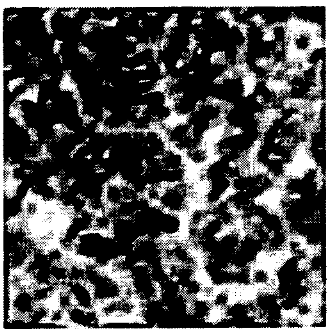


Fig. 6. Negative of variance image.

As shown in Fig. 6, this image consists of linear components and non-linear component slopes that have a direction parallel with sun azimuth angle. Therefore, non-linear component slope must be deleted from linear components. In this paper, slope parallel with sun azimuth angle has a higher or lower DN than valley or ridge. However, we remove such a slope because it is not considered as linear component in this paper. To delete it, we ignore the values greater than an upper limit or smaller than a lower limit.

EDGE LINKING AND VECTORIZATION

Hough Transform was introduced by Hough (1962) and many scientists have implemented it. Usually the polar parameter space is used to link points for making straight lines in an image. The transform equation is given by

$$\rho = x\cos\theta + y\sin\theta$$

, where x and y represent the coordinates of pixel in the image with respect to X and Y axis, respectively. θ is an angle and ρ is the distance to the origin. Every point is mapped onto the $\theta - \rho$ plane and the corresponding cell in accumulator array is incremented by one, where accumulator array represents the polar parameter space. To keep the original coordinates of pixels and find a starting point of each line easier, we utilized another array. Each element of the array is implemented by using Single Linked List(SLL) because each element should keep track of all the pixel coordinates which cause the corresponding cell of accumulator array to be increased. Our vectorization steps are the followings. Firstly, we use the image through edge detection and line detection filters to produce a Hough image. In that time, each pixel coordinates is also added to the corresponding SLL. The advantages of using SLL are that we can trace the coordinates of all pixels associated with each cell in the accumulator array and that de-Hough processing is not needed. And then the image is normalized by a surface of maximum possible values which is equivalent to the result of Hough-transforming a white tile (Fitton and Cox, 1995). Finally we extract and link straight lines using the accumulator array and SLL array. In the final step, a cut-off parameter is used to detect only local maxima in the accumulator array whose values are equal to or greater than the cut-off percentage of the global maximum values. Also, we can define the maximum distance between neighboring lines to be connected and the minimum distance of a straight line using other parameters. Fig. 7 was generated with the cut-off value, maximum between neighboring lines to be connected and minimum distance of a straight line; 80, 5 and 70, respectively.

Fig. 7 Result image.

Discussion & Conclusion

The result of extraction of linear feature is usually diverse depending on which filters would be used. Therefore, the selection of the proper edge or line detection filter is very difficult but important. In general, the smaller masks are sensitive to noise, whereas the larger masks cannot resolve fine detail and may have difficulties if the linear components are of similar size (Nevatia and Babu, 1980). We chose a lager mask because small linear components would not be utilized in this paper. In the case of the variance image, linear components were more distinct and clear with using a 5x5 average mask than in a 13x13 mask. We induce from this result that a larger average mask could not detect ridges or valleys, especially if their size is very small. Also we can remove slopes from the variance image by ignoring values greater than a given upper limit or smaller than a given lower limit, commonly called a threshold value. Finally, the linear components through the edge and line detection filter were linked appropriately with the degree of neighborhood on Hough transform. In this paper, we implemented the Hough transform to trace the original pixel coordinates using a SLL array as well as an accumulator array. To produce a good result, three parameters should be manually adjusted during the Hough-transforming.

The final result shows that the new filter and algorithm developed in the study is effective to detect the linear components (Fig. 7). Our further study is to reduce the number of parameter which should be manually input.

ACKNOWLEAGEMENTS

This paper was supported by Center for Mineral Resources Research (CMR). The authors would like to thank Mr. Sang Wan Kim for providing the test image.

REFERENCES

Ben A. van der Pluijm and Stephen Marshak, 1997. *Earth Structure : An Introduction to Structural Geology and Tectonics*, McGraw-Hill, 143p.

Fitton, N. and Cox, S., 1995. Linear Feature Extraction in Geoscientific data, Australian Geodynamics Cooperative Research Centre.

Hough, P. V. C., 1962. Method and Means for Recongnizing Complex Patterns, U.S.Patent 3069654.

Koike, K., Nagano, S. and Ohmi, M., 1995. Lineament Analysis of Satellite Images using a Segment Tracing Algorithm(STA), *Computers & Geosciences,* 21(9), pp. 1091-1104

Lee, K.W. and Chi, K.H., 1995. Spatial Integration of Multiple Data Sets regarding Geological Lineaments using Fuzzy Set Operation, *Journal of Korean Society of Remote Sensing*, 11(3), pp.49-60.

Nevatia, R. and Babu, K. R., 1980. Linear Feature Extraction and Description, *Computer Graphics and*

Image Processing, 13(3), pp.257-269.

Robert, L. Bates and Julia, A. jackson, 1987. *Glossary of Geology, Third Edition* : American geological institute, 380p.

Won, J. S., Kim, S. W., Min, K. D. and Lee , Y. H., 1998. A Development of Automatic lineament Extraction Algorithm from Landsat TM images for Geological Applications, *Journal of the Korean Society of Remote Sensing*, 14(2), pp. 175-195.