Comparative Study of GDPA and Hough Transformation for Automatic Linear Feature Extraction

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Abstract: As remote sensing is weighty in GIS updating, it is indispensable to get spatial information quickly and exactly. In this study, we have designed and implemented the program by two algorithms of GDPA (Gradient Direction Profile Analysis) and Hough transformation to extract linear features automatically from high-resolution imagery. We applied the software to embody both algorithms to KOMPSAT-EOC, IKONOS, and Landsat-ETM and made a comparative study of results.

Keywords: GDPA algorithm, Hough transformation, high-resolution imagery

1. Introduction

Linear feature extraction using remotely sensed imagery is one of the important tasks in remote sensing applications and lineage of remote sensing and GIS. Conventionally, several kernel-based line and edge detection methods for extracting linear features from remotely sensed data are known. While, with increasing available satellite imagery from different types of sensors, new methods for automatic feature extraction have been developed. As remote sensing is weighty in GIS updating, it is required to get spatial information quickly and exactly. If human do this task personally, it takes a lot of time and the processed results might be inconsistent. In this study, we have designed and implemented the program by two algorithms of GDPA (Gradient Direction Profile Analysis) and Hough transformation to extract linear features automatically from high-resolution imagery using and evaluated them in the aspect of practical applications. The software to embody both algorithms was developed under MS visual programming environment, with graphic user interface in this study and performed comparative study with KOMPSAT-EOC, IKONOS, and Landsat-ETM.

2. Methodology

The procedures involved in preprocessing, linear feature extraction and post processing are illustrated in Fig.1. Preprocessing included smoothing and sharpening. In this study, a 333 filter was applied to the data. In the part of linear feature extraction, the Gradient Direction Profile Analysis proposed by Wang [1] and Hough transformation developed by Hough were used. Subsequently, thinning algorithm proposed by Zhang Suen was applied for detecting central line of road and sobel mask was applied for detecting boundary of road. After the procedures that are illustrated in Fig. 1 were over, we removed noise from output images, formed road network. For the last time, we compared results with existing digital GIS road layers.

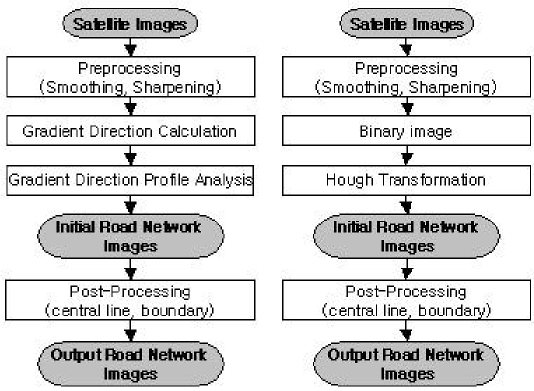

Fig. 1 the flowchart about road extraction procedures.

1) Gradient Direction Profile Analysis

The GDPA algorithm was initially proposed by Wang (1992)[1] 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 the 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

$$K(x)= |f0(x)|/(1+f9(x)^2)^{3/2} \qquad (2)$$

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

2) Hough transformation

Hough algorithm uses a parametric description of simple geometrical shapes in order to reduce the computational complexity of their search in a binary image. It is reported that these algorithms are useful respectively for linear feature extraction tasks. This method involves transforming each of the figure points into a straight line in parameter space. The set of all straight lines in the image constitutes a pair of two-parameter. In geometry coordinate system, the equation of a line is represented to

$$x\cos\theta + y\sin\theta = \rho \qquad (3)$$

If we restrict θ to the interval $[0, \pi]$, every line in the x-y plane corresponds to a unique point in the θ-ρ plane. If any line passing through the point (x, y) is detected during scanning image, we add 1 to $P(\theta, \rho)$. After the end of the procedure, each parameter matrix element $P(\theta, \rho)$ shows the number of binary edge detector output pixels that satisfy Eq. (3). If this number is above a certain threshold a line of the form Eq. (3) is declared.

3. Results and Discussion

We applied two algorithms of the GDPA and Hough transformation to three types of remotely sensed data (Landsat-ETM, KOMPSAT-EOC, IKONOS) with different spatial resolution (30m, 6.6m, 1m). The study area was Guri and Namyangju nearby Seoul, Korea. The results were quite different from different algorithms, variables and sensors with different resolutions.

Users can change the length of profile and the curvature limit at GDPA algorithm. At Hough transformation, variables are the threshold for a binary image and the limit of accumulated value at parameter space. As shown in Fig.2, each result is different, if variables are changed. While the curvature limit value, the threshold for binary image and the limit of accumulated value at parameter space decreased, the noise increased and we lost in quality.

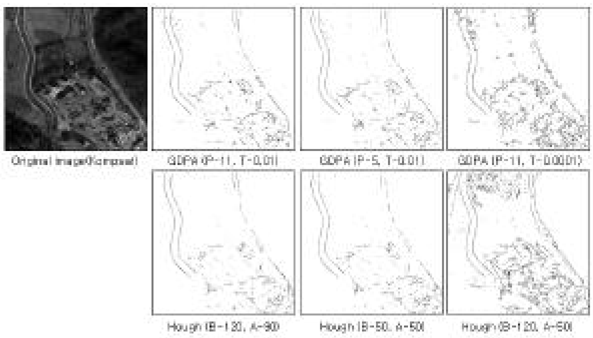

Fig. 2. The comparative study according to changing variables. P, T, B and A mean the length of profile, the curvature limit, the threshold for binary image and the limit of accumulated value at parameter space.

Sensors as well as variables influenced the results. This means not only quality but also available results were transformed. High-resolution images, such as Kompsat image and IKONOS image let us detect boundary of roads as well as central lines. (Fig.3) But, the only central line was detected from Landsat image (low-resolution image) and the results were poor compared with the other two. (Fig.4)

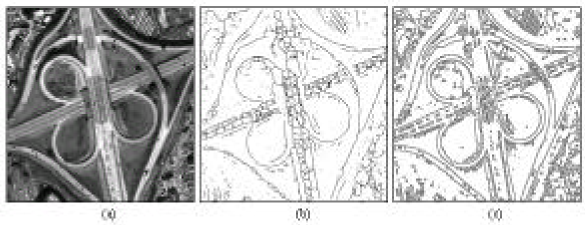

Fig. 3. The central lines and road boundaries that we extracted from Kompsat image.

The difference according to algorithms is shown by Fig.4. If the digital value of each road is different from others in one image, to use the GDPA algorithm was profitable. If the radiometric contrast between roads and surroundings is dissimilar, roads are detected using the GDPA. Also, the GDPA could describe local conditions of features. To extract all kinds of features was feasible using the GDPA algorithm. So, it could be detected the real types of roads similarly. It also took less time than Hough transformation. But, Similar radiometric contrast between roads and surroundings provided bad result. If the length of profile is shorter than the width of the road or too long, we can’ t expect good results. Because every feature was detected without regard to length, the result had a lot of noise. Although we removed noise using the curvature, pruning is necessary for completed road network.

On the other hand, Hough transformation was effective, if the digital value of each road is similar to others in one image. Because Hough transformation includes the procedure of making binary image, a fine result can be acquired using a fitting threshold. The results had less noise in comparison. But, the detectable features using Hough transformation were restricted line and circle. It was more time consuming task compared with GDPA.

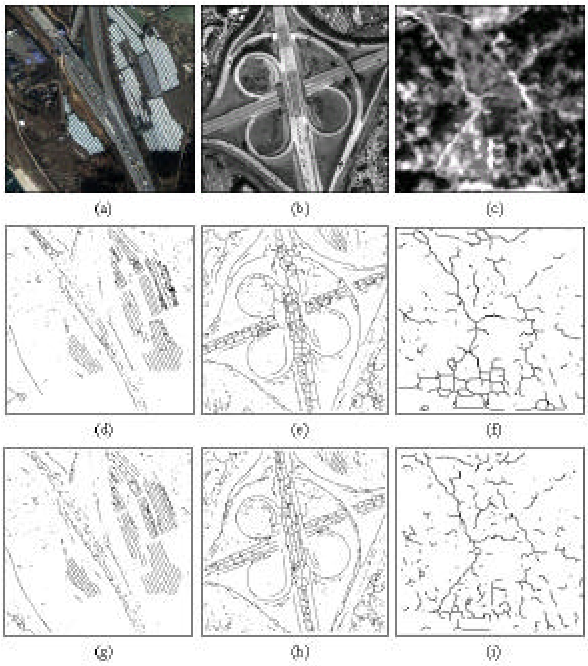

Fig. 4. Road extraction for Guri and Namyangju (a), (b), (c) are IKONOS(1m), Kompsat(6.6m) and Landsat(15m) original image. (d), (e), (f) are results of Hough transformation. (g), (h) and (i) are results of GDPA algorithms

For the quantitative evaluation, the results produced by two algorithms should be compared to roadmap generated by manual digitization of the roads. The used method was proposed by O’ Brien(1991)

$$\text{ranking} = 200/((1+\text{omission})3(1+\text{commission})3(2+|\text{omission}-\text{commission}|)) \quad (4)$$

The overall accuracy is the fraction of pixels correctly extracted as roads. The commission error is the number of pixels incorrectly extracted as road pixels. The omission error is one minus the overall accuracy. The range of the measure of ranking is from 0 to 100, with higher figures representing better results.

In view of the results so far achieved, the processes, which connect the broken parts of the roads and diminish noise, are necessary for updating of GIS road layer. To remove features, which have shorter length than given value can be used for diminishing noise. To connect the broken parts of the roads, connecting vertex within a constant distance can be used. Also the extracted road feature should be vectorised.

4. Conclusion

In former days, we could know the existence of road form low-resolution image. But, as high-resolution images, such as Kompsat image and IKONOS image were used, we could extract boundaries of roads as well as central lines. The GDPA algorithms needed a length of profile and a curvature that user determine. For Hough transformation, the threshold for binary image and the limit of accumulated value at parameter space were needed. The GDPA algorithm was useful, when the digital values of each road were different from others in one image and the shape of road was complicated. Hough transformation was suitable when the digital values of all roads were similar, original image had a lot of noise, and the road shape was simple. If we use results as road network, further improvement is needed to process the road maps in other to connect missing road segments and to remove the extraneous elements that are mistaken as roads.

References

[1] J.Wang, Q.Zhang, 2000. Applicability of a Gradient Profile Algorithm for Road Network Extraction – Sensor, Resolution and Background Considerations, *Canadian Journal of Remote Sensing*: pp. 428-439

[2] Kiwon Lee, Young Chul Yu, 2002. Automatic Extraction of Road Network using GDPA (Gradient Direction Profile Algorithm) for Transportation Geographic Analysis, *Proceedings of International Symposium on Remote Sensing*: pp.775-779

[3] Jinfei Wang, Philip J.Howarth, 1990. Use of the Hough Transform in Automated Linearment Detection, *IEEE Transactions on Geoscience and Remote Sensing*: pp.561-566

[4]E.R Davies, 1997. *Machine Vision: Theory, Algorithms, Practicalities*, Academic Press