Road Extraction in Urban and Suburban Area Using a Contextual Method

Tian Lianghu

Lecturer, Department of Earth Science
Zhejiang University, Hangzhou, China.
Commission III

Abstract:

Linearment enhancement is one important subject of remote sensing. Many methods and algorithms for linearment enhancement have already been presented and designed which generally use the abrupt change of brightness on the edge of linearments. These methods, however, have one shortcoming that they are not efficient if much more noises exist in the image or there are less brightness change between the background and linearment. This paper presents a contexual method to extract urban road and suburban railway in Yueyang district of Hunan Province using the shape information. It is known that roads are such linearments that they are overlayed on a homogeneous background which differs from other linearments like the edge of two bodies. This enables the clustering technique instead of general enhancing methods to conveniently and efficiently enhance the road information in which much more other non—road noises are contained. Then contexual information, the ratio of the length to width, is used to eliminate the non—linearment noises. A mass centering method is developed to connect the continual points on the road linearment which can form a complete line and has no effect on the adjacent points. Another algorithm is designed to extract the length and width of the line in which the continuity is considered that differs from general convolution technique. The ratio of the extracted length and width is used as contextual information to remove the other non—road pixels. The result shows that this method is considerablely efficient to extrat the road features in the urban and suburban area on the remotely sensed data. Furthermore, it is helpful for monotoring the urban road distribution and the urban expansion.

Keywords: Pattern Recognition, Feature Extraction, Classification, Algorithm

1. INTRODUCTION

The linear feature is the one important characteristic on the remote sensing image. Linearments on the image contain mainly two types. One is the edge boundary between two regions of different constant grey level. The ideal step edge has the cross section shown in fig. 1. Another is the linear object which occurs in a large homogeneous object such as road. Fig. 2 and fig. 3 show the basic linear objects on the images. In real conditions, these linear objects always present the case as fig. 4.

The detecting and extracting of the linear features on the remote sensing image have been studied by many scientists and experts. Various methods and approaches have been developed which use diverse masks covered on the image to detect abrupt changes of grey level. These approches can be used to detect the roads in the case discussed above. But in many cases, it exists great varieties of noises and the roads can not effectively be extracted.

It is obvious that previous methods developed for edge detection are used only on single band image data. They

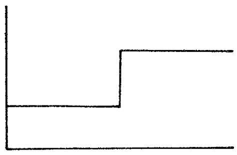

Fig. 1 An ideal step edge

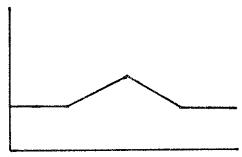

Fig. 2 A roof line

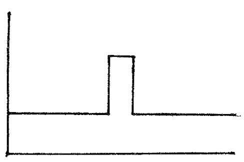

Fig. 3 A rectangle line

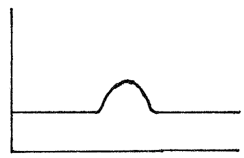

Fig. 4 A real line

have no ability to integrate multi-band information. It is impossible for these methods to detect and extract the road when road has the similiar gray level with its background on single band image.

In this paper, one contextual method simulating the visual interpretation is developed to extract the road features. It uses the shape information that is long lenth and narrow width to detect and extract road features. It also can integrate the multi-band information. It was found that roads extracted by this method are almost identical to those produced by field investigation.

2. STUDY SITE

The TM data were obtained on August 25, 1987 from the Chinese Satellite Ground Station (CSGS). CSGS provided both the false color composited photo and computer compatible tape(CCT). The study area was selected to the Yueyang City, Huan Province (see fig. 5). The downtown area, in the northern part of Hunan Province, has about 300,000 population. Great Dongting Lake is adjacent at its west and the Yangzhi River at its north. Beijing to Guangzhou railway passes the whole area. It is developed rapidly in the recent years and now is the one most important base for industry, transportation, aquatic production and agriculture.

Yueyang city expands median-small urban area. The

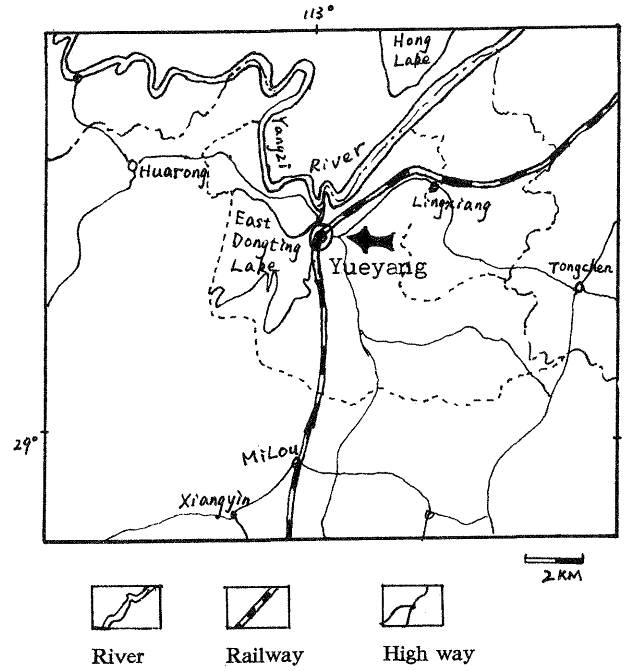

Fig. 5 Study site of Yueyang city

complexity of road distribution increases difficulty of the extraction of road system from TM data.

3. ANALYSIS AND ALGORITHM

For more than a decade, efforts to extract information from multispectral remote sensing image data have proved increasinly successful. To a large extent, these efforts have focused on the application of pattern recognition techniques to the multispectral measurements made on individul ground resolution elements, i. e., scenes have been classified pixel-by-pixel based on the measurement vectors associated with the individual pixel. However, sole spectral information is not adequate to recognize the road features. There are many applications for which the classes of interest can be better characterized if the spatial information in the remote sensing data is utilized in addition to the spectral information. Characteristic spatial features include, for example, texture and context. Contextual information generally indicates the structural relationships between pixels.

One way to approach contextual information is to utilize the shape information. One particular target is the object with regular shape projecting on the image. Shape information takes the important role in the visual interpretation. The accuracy of the visual discrimination of particular object will increase with the pixel resolution higher.

Road feathure is one of the particular target. Auto-recgonition of it by computer is usually implemented by line detecting techniques. Conventional linearment detecting methods are solely on the basis of the abrupt change of grey level. Beside roads, other linear feature with the similar situation will also be detected and demonstrated by these methods.

It is known that roads possess two characteristics. One is spectral information. It is impossible to extract road using sole spectral information because there exist other objects with the same spectral reflectance. Another characteristic is its linear contextual or shape information. The ratio of the lenth to width can be regarded as its significant contextual information to be used in the discrimination of the road. It is possible that the integration of the spectral and shape information can reach the effective extration of the roads.

This paper designs an approach which integrates the spectral information and shape information. The procedure contains two steps. First step is to classify and segment the roads using multiband spectral data. Second step is to remove other noises and remain the road points using the ratio of its lenth to width. One algorithm to caltulate the lenth and width is also developed. A mass centring method is also developed to connect the continual road pixels by which the adjacent points near the road are not affected. The test shows that the result by this method are almost identical to those interpreted from the aerophotographes and those produced by field investigation

3. 1. Spectral Classification

It is significant to consider the combination of the two steps to reach the best achievements. Completeness of road must be emphasized in the spectral classification in order to compute the ratio of the lenth to width. The process of classification should focuses on the connexion of the road points instead of the precision of the classification. While the next shape classification focuses on removing produced noises and extracting roads. Thus, the spectral classifier is designed as follows:

Assume j bands are token into classifier. Select some samples for trainning. Let a_i and $s_i (1 \leqslant i \leqslant j)$ stand for average and mean square deviation respectively of the road grey level in ith band ($1 \leqslant i \leqslant j$), $(r_1, r_2, \cdots, r_j)^T$ stand for the spectral vetor of any pixel in the image. If $|r_i - a_i| \leqslant cs_i$ for $i = 1, 2, \cdots, j$, c is a constant, then this pixel was discriminated to the road. According statistic theory, when $c = 2$, 95 percent of all road pixels were correctly classified. Thus a road distribution picture was obtained in which road shape was completely remained.

3. 2. Shape Classification

It is obvious that in the picture obtained from spectral classifier exist lots of other non-road objects or noises. Almost all these objects or noises are not linear in the shape. Shape information can be used to eliminate the noised.

One pixel in the image possesses eight neighbor points as fig. 6. If we regard two opposite points as one direction, every pixel radiates outside on four directions. We can calculate the four radiated distances s_1, s_2, p_1, p_2 on these four directions for each pixel (fig. 7). Let $R = max(s_1/s_2,\ s_2/s_1,\ p_1/p_2, p_2/p_1)$. If the pixel is true road point, the value R on this pixel must be greater than those false road points because the road has large lenth

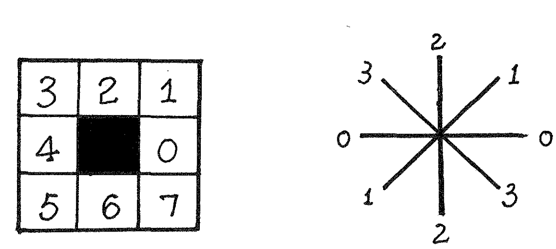

Fig. 6 The dark square at the center shows the pixel in which one is interested. The pixel has 8 neighbors from 0 to 7 and four directions from 0 to 3.

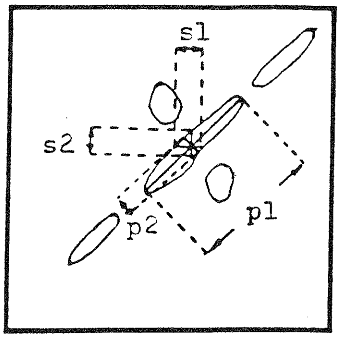

Fig. 7 Radiated distances on four directions

1	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	0	0	0	1	0
0	0	0	1	0	0	0
0	0	0	0	1	0	0
0	0	0	0	0	1	0
0	0	0	0	0	0	1

Fig. 8 The broken point on the road

1	0	0	0	0	0	0
0	1	0	0	0	1	0
0	0	1	0	0	1	0
0	0	0	1	1	0	0
0	0	0	0	1	0	0
0	0	0	0	0	1	0
0	0	0	0	0	0	1

Fig. 9 Connetion result after mass centring

and lttle width. If given a value T , when $R \geqslant T$, the pixel can be discriminated to the true road.

It is often that on real line in the image exists random broken points. (see fig. 8). It causes much trouble and difficulty for radiated distance calculating. A mass centring algorithm is designed to fill these broken points. The average coordinates were calculated within a given window. The point on the average coordinates then is given the same value of the line point. Fig. 9 demonstrates the result by this algorithm. The characteristic of this algorithm is that the values on the adjacent points near the line will not be affected. Widow sizes determine the lack pixel number being connected. For example, 3×3 window can connect broken points with one lack pixel, 5×5 window can connect broken points with two lack pixels. In the test, 3×3 and 5×5 windows were used gradually.

4. RESULT AND DISCUSSION

Fig. 10 is the road distribution picture produced by the procedure. In fig. 10, the urban road system within the white frame and the railway outside are extracted respectively from the TM data. The railway was combined with one main city road when pass in to the city and went out on the south. TM band 1,3,4,5 were selected to spectrally classify the railway and TM band 5 was used to segment the urban roads because these bands possess particular characteristic for roads classification. Result picture is also implemented thinning processing.

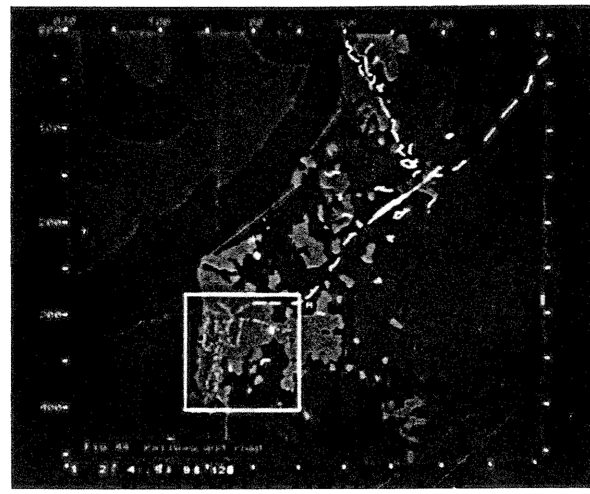

Fig. 10 Road distribution picture. In the white frame is the urban road system and outside is the railway. Railway was combined with one city road when passed in to the city.

The comparison with the aerophotograph and field investigation show that this map demonstrated correctly the railway and indicated almost the whole urban road system. Only two small roads in the western city were partially or not demonstrated. This shows that the contextual method simulating the visual interpretation is correct and the algorithm designed is effective.

In the process of evaluating these results one can observe an obvious phenominon that the whole road was isolated to several fregments. This was caused by two kinds of errors. A) errors due to the spectral classification. The path that road passes possesses complex surroundings. The reflectance of some road elements may be affected and changed by surroundings. B) errors due to contextual method. The greater curvature of road may cause the ratio of the lenth to width lower.

5. CONCLUSIONS

In this paper we have presented a program which recognizes real roads. This program can integrate the spectral and spatial information in extraction of particular target. It can simulate the visual interpretation to recognize the roads. The ratio of the lenth to width of road is proved to be the special information to successful discrimination of the road.

Although there are broken fragments on the road line in the result picture, the accuracy by this program is much better than those by conventional methods.

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REFERENCES

1. Barry, N. H. , 1984. Multisensor data analysis of urban environments. Photogrammetric Engineering and Remote Sensing, Vol. 50, No. 10, pp. 1471—1477.
2. Charlotte M. G. and J. R. G. Townshend, 1983. The use of contextual information in the classification of remotely sensed data. Photogrammetric Engineering and Remote Sensing, Vol. 49, No. 1, pp. 55—64.
3. Philip H. Swain, Howard Jay Siegel, Bradley W. Smith, 1980. Contextual classification of multispectral remote sensing data using a multiprocessor system. IEEE Transactions on Geoscience and Remote Sensing, Vol. GE-18, No. 2.
4. Ruzena Bajcsy, Mohamad Tavakoli, 1976. Computer recognition of roads from satellite pictures. IEEE Transactions on System, Man, and Cybernetics, Vol. SMC-6, No. 9.
5. Stephen W. Wharton, 1982. A contextual classification method for recognizing land use patterns in high resolution remotely sensed data. Pattern Recognition, Vol. 15, No. 4, pp. 317—324.
6. Tian Lianghu, Zhao Yuanhong, Zhan Fuxiang, 1990. Urban thematic information extraction and dynamic extension detection. Proceedings of the 11th Asian Conference on Remote Sensing, Q-37-1-Q-37-6.
7. Tian Lianghu, 1991. Detection of the developments of urban area using remotely sensed data. Remote Sensing Application, Vol. 4, No. 1, pp. 28—35.