ROAD EXTRACTION FROM HIGH-RESOLUTION REMOTE SENSING IMAGE BASED ON PHASE CLASSIFICATION

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ABSTRACT:

It is still an open problem to extract road feature from high-resolution remote sensing image, although this topic had been intensively investigated and many methods had been put forwards. All works for this thesis are focused on modern urban road and include the following four steps: image pre-processing, threshold calculation, feature extraction for straight line and curved line, target reconstruction. In this contribution, a new and semi-automatic approach is proposed based on phase classification. Firstly, basic road network can be obtained from high-resolution remote sensing image based on grey level mathematical morphology and ***canny*** algorithm and then road information can be exactly extracted by means of the "grey" parameters which are various for different kinds of road models based on the theory of phase-based classification. Additionally, the proposed method can also be employed to elevate urban highways, especially for the curve parts of which. The extracting results are reasonable.

1. INTRODUCTION

The high-resolution remote sensing image is usually refers to the image with its spatial resolution of the pixel below 10m. In the 1960s, the research on special high-resolution sensor reached a plateau of development and a lot of sensors with high-resolution were invented at that time, such as IKONOS, QUICKBIRD and so on. With the rise of special resolution, more and more details will be showed clearly, which could provide a reliable foundation for the work of extracting objects from high-resolution remote sensing image accurately.

With the development of city, the objects become various, like building, park, athletic field, open area and so on and each one of which has itself complex structure and shape. It is rather hard to extract the different objects one by one and just do cost much time, and therefore, the extracting work can barely be set up in application. However, we all know that urban road is the main clue to analyze and interpret the city. So we can extract road information from urban remote sensing image first, and then analyze each district segmented by roads. By doing this, the analyzing work will be easier than before.

There have been many researches on the approaches of road extraction (Shi et al. 2001). These can be divided into the semi-automatic type (Li et al. 2004) and totally automatic type. Semi-automatic extraction for road feature takes advantage of man-machine interactive form to recognize the objects. Its main idea is consist of two steps. At first, give the initial pixel manually, sometimes even the initial direction. Finally process the image by computer. Studies on the aspect have received accurate effect. We can arrange it under the following approaches roughly. That is, road extraction from remote sensing image based on two-dimension wavelet transform(Zhu et al. 2002); Road extraction based on pixel and background arithmetic operator; Road extraction based on tree-structure model of feature cognition, which is fit for middle & low resolution image; Road extraction based on least square B-spline curve; Road extraction based on heuristic graph search . This approach has strong noise immunity; Road net extraction based on class and fuzzy sets (Gruen et al. 1995); LSB-Snakes approach (Trinder et al. 1997).

At present, there isn't a more generic road extraction system with complete autoimmunization. But some successes on a particular type of road extraction have been achieved, from which many meaningful algorithms have been attained. For example: road extraction based on parallel lines; road extraction based on the bi-value knowledge(Song et al. 2005); road extraction based on the characteristic of the window model; Besides described above, there are also other algorithms on automatic feature extraction. In the thesis" Fundamental Limits of Bayesian Inference: Order Parameters and Phase Transitions for Road Tracking" (Yuille et al. 2000), a popular approach has been studied. Because there is no exact image for experiment, it has more theoretical signification.

Traditional approaches on road extraction tend to extract the linear road. The accuracy is relatively low in extracting the urban road. There also exist omissions in some images because of the tiny, closed and preserved features. Sometimes the road in the image is close to the background, which could go against extraction. And a suitable algorithm for urban highways in modern days hasn't been applied in traditional approaches. Aiming to the shortfalls above, this paper proposes a new approach. That is road extraction based on Phase Classification. Not only be fit for the road extraction of general shapes, but also having certain superiority in the detection work of urban

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highways. This paper is organized as follows. Section 2 will present the question of "what is phase classification". Section 3 will explain the thesis of this paper used in the work of road extraction. Section 4 will show the experiment on the road work. The final section will give the conclusion to the improved approach on road extraction in high-resolution remote sensing image.

2. PHASE CLASSIFICATION METHOD(RAO H., 2004)

General algorithms of edge detection often refer to the gradient information of image, such as gradient algorithm, Laplacian algorithm, Marr algorithm and so on. The main idea of it is to calculate the gradient scope of one point whether it is over the pre-threshold. If over this pre-threshold, there will exist the edge, or there will not. Base on the method of gradient, it is thought that the edge exists in the changing area of the grey. But the effect is not obviously to the images with even grey. Burns and other persons thought the edge exists not only in the changing area of grey, but also in the place where the grey changes in one following direction. So Burns proposed a method for the work of extracting the straight line based on the phase characters of edge, which is named phase classification. This method is very effective to extract the edge and outlines of images. The exact algorithm in the following is:

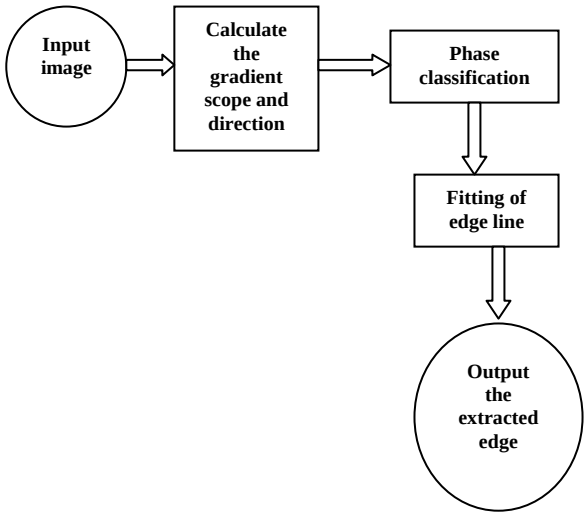

Figure 1. Chart of Phase Classification

Input the pixels of one image line by line, and then calculate each difference of every edge pixel in the direction X, Y, which is D_x and D_y. Finally we can get the tangent value of each point, $arctg = (D_y / D_x)$. It is also the gradient direction, which refers to the most severe direction compared to its adjacent points. The relevant formulas are:

$$D_x = p[x-2, y+1] + p[x-1, y+1] \times 2 + p[x, y+1] - p[x-2, y-1] - p[x-1, y-1] \times 2 - p[x, y-1] \quad (1)$$

$$D_y = p[x, y-1] + p[x, y] \times 2 + p[x, y+1] - p[x-2, y-1] - p[x-2, y] \times 2 - p[x-2, y+1] \quad (2)$$

$$\theta = arctg(D_y / D_x) \quad (3)$$

$$M = |D_x| + |D_y| \quad (4)$$

where D_x = horizontal difference.

D_y = vertical difference.

θ = gradient direction.

M = gradient scope.

In the method of phase classification, put all the points that belong to the same direction area and connect each other in geometry into one class, which is the edge class. In fact, the grey of most points in image changed gently, so we make the value M over the pre-threshold into the classification. In order to reduce the processing data column in the following steps, we see the adjacent points, as well as have the same value θ, in the horizontal direction as one code. Then compare the code of one row to the one of the previous row, class the points which have the same code into the same area. After doing these works, mark all the edge points with the number one to eight. Like figure 2:

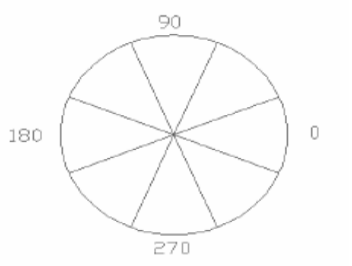

Figure 2 Chart of Dividing the Gradient Directions

After divide all the edge point, fit them that belong the same area with the method of least square to extract the edge line exactly.

3. ROAD EXTRACTION BASED ON PHASE CLASSIFICATION

Road in high-resolution remote sensing image includes following five characteristics:

1）Narrow width and smooth curve;
2）Direction changes smoothly too;
3）Internal grey values are even;
4）Gray values inner differ much from that of background;
5）A certain length of the road;

Aiming to these characteristics above, this paper proposes a new method in extracting road information from high-resolution remote image. This method is based on phase classification.
Firstly, define threshold automatically taking advantage of ***canny*** operator. Secondly, transform the original image into a bi-value one. Finally, improve the phase classification method in order to extract different kinds of road. This approach is almost automatic without given initial coordinates as well as

direction parameters. The aspects of accuracy and efficiency have been improved greatly. Operating steps can see the following chart:

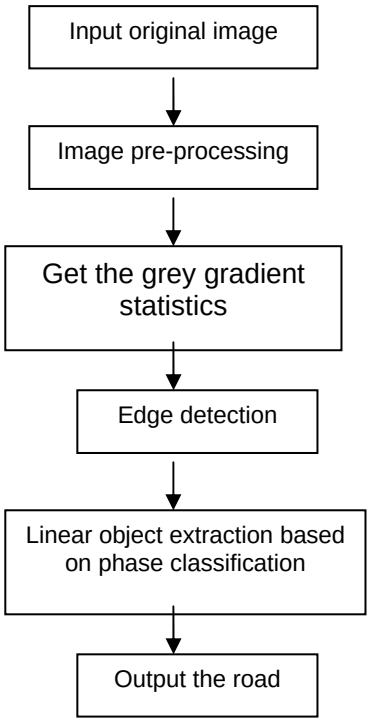

Figure 3 Flowchart for Road Extraction

3.1 Edge Detection(Rafael C. , 2004)

In order to apply the method of phase classification effectively, the step of edge detection is very important. Enough edge information can be useful to the work of road information extraction.

Till now, there have been many operators(Chen Y. 2003) for edge detection, such as Robert, Log, Sobel, Canny and so on. Analyzing these existed methods, we decide to use Canny to go on with the work of edge detection as well as the method of grey morphology.

Firstly, with the knowledge of grey morphology (Zhu et al. 2004), the image will be corroded and inflated once. In this way the roads that are fuzzy can be improved. Meanwhile the information of the road's edge can be strengthened. Secondly, improve the Canny operator, take advantage of the double thresholds to detect the light edge parts and the dark parts. Based on the principle of non- local maximum suppression, we can get the edge information in detail. Finally, thin the edge line with the method of skeleton extraction in the area of morphology, which can we get the road edge line of single pixel. By this step of edge detection, the edge information could be preserved most which is useful to do the following work.

3.2 Grouping Road Edge and Re-fitting Line in Image

According to the phase and amplitude information accounted, group the edge of the road edge lines, and then fit them into straight lines and curves.

3.3 Determination of Initial Point on Road

According to the method described in chapter 2, calculate the phase information of the edge image, then combine this information with the gradient scope, group the edge points, finally fit the edge line using the method least square, which can we get the straight lines and the curve lines, those are all road edge lines. Taking into account the shadow shielding near the road, we can judged the initial point of the road by the following criteria,.

1) The width of the road at this point should be consistent with the given width of the road.

2) The grey value at this point should be consistent with the given value more or less.

3) Search for eight neighbourhoods of this point. Except for this point, if pixels in its eight neighbourhoods contain one edge point, this point can be seen the starting point of the road. It can be interpreted by the following chart:

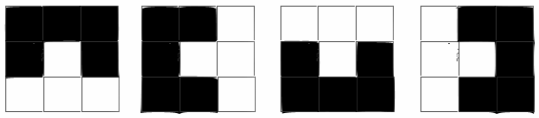

Figure 4 Search the Eight Neighbourhood of the Starting Point

3.4 Track binary image to acquire supported region for road edge

From the lower left of the image, search binary edge image line by line. From the starting point, calculate its gradient direction, mark the gradient direction of this pixel values as $k(k = 0,1,2,\cdots,7)$, and then search its eight neighbourhoods. If there exit pixels that belong to the same area named k, put this neighbour point into the same road line with current pixel. In the computer, we can note it into an array to store safely. Arrange the new point as the current one, do the same search work in the way described above until all the pixels in the marked area have been detected. All the points searched belong to one array. Similarly, search the total edge image to account points of the same type in each area of road into a linked list in computer.

3.5 Improve the method of phase classification to fit the road line

In the 3.2.2, we described the traditional method of phase classification to get the edge line of the road. Now some points of the method have been improved in order to get various kinds of road line in image. That is, fit the three adjacent points into a line by least squares method respectively. Calculate each value of slop from every three adjacent points, namely a_1, a_2, a_3. Set a threshold, namely: T1. From many examinations, here we can define T1 to be $\frac{1}{2}$.If the calculated slopes meet the condition $0 < a_1, a_2, a_3 < \frac{1}{2}$ at the same time, and we define them as the same road points.

In the corresponding position in original image, draw the red line to connect detected three points. If the point does not conform to the rule, remove it. Take the same steps to the following groups until it reaches the end.

Get the statistics for each road to determine the length and location. According to the given threshold (T2) of the road length to judge the line is whether the road edge line. Removed the one which is less than the threshold value, retain a certain length of the straight line or curve. We think it as the road that we extracted. Based on this perceptual grouping principle, not only the edge of the single-shape road can also be detected in the image as well as the crossing parts and the corners at last.

According to the characteristics of four roads, shape and grey value of the extracting region, the road model and the knowledge of the road, road region from the initial image is extracted, that is road edge lines.

3.6 Extracted Road in Original Image

With coordinate information, draw the red line on the original image, which stands for the edge line and centre line of the road. This can indicate the right location of the road information clearly.

4. EXPERIMENT

4.1 Experimental Data Resource

Data source in experiment comes from Quick Bird remote sensing image with 0.6m resolution, which shows the region of Lujiazui in Shanghai. Crop four sub-images(Figure 5-8) with four different types of road information on them. Test this improved method approached in the paper. All the algorithms are implemented in the VC 6.0 environment.
Experimental image Figure 2-5

Figure 5. Single-Shape Road(1079×400)

Figure 6.General Crossing Road (1992×2046)

Figure 7. Cruciform Cross (2394×1740)

Figure 8. Elevate Urban Highways (1020×1644)

4.2 Result of Edge Detection

Edge detection image after using algorithm mentioned in 3.1.

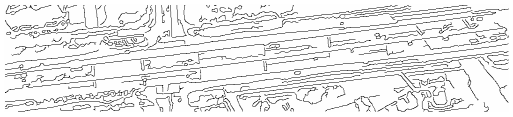

Figure 9. Edge Detection to Figure 5.

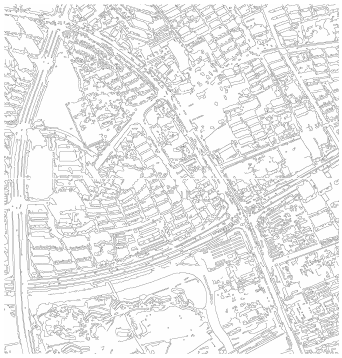

Figure 10. Edge detection to Figure 6.

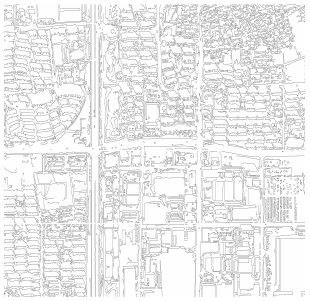

Figure11. Edge to Figure 7

Figure 12. Edge to Figure 8

4.3 Experimental Result

Figure 13 to Figure 16 are the final images after the work of extraction. Red lines refer to the edge lines and the centrelines of the road, overlapping into the original image. You can see the road information more conveniently.

	Single-Shape Road	General Crossing Road	Cruciform Cross	Elevate Urban Highways
T2 (pixel)	100	50	60	35

Table 1 Set the value of T2

From the table 1, we can see that different shape of road has different the value of T2.In general, the more complicate shape of road, the less the value of T2.

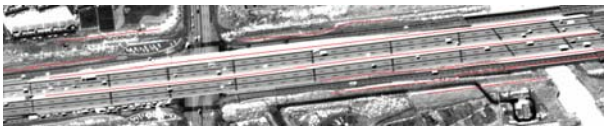

Figure 13. Extraction Result of Single-shape road

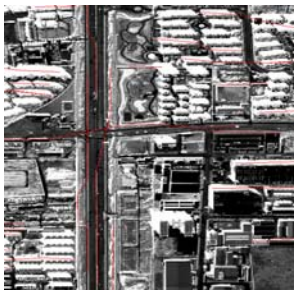

Figure 14. Result of Crossing Road Figure 15. Result of Cruciform Cross

Figure 16. Extraction Result of Elevate Urban Highway

From the results, we can get the conclusions that the method proposed

1) There is a great accuracy (Figure 13)in extracting road with single shape(Figure 5). Edge line and the centrelines of the road can be showed exactly.

2) To the roads whose surface has many branches (Figure 6), the extraction result is not very good (Figure 14). One branch has not been extracted accurately. The reason for it is that in the same area, different branches have different grey value, which will be unable to extract all of the branches totally.

3) Cruciform cross (Figure 7) is one of the most popular kinds of road, which consists of two simple crossing lines. Although the extracting result is not better than 1), cruciform cross has been marked obviously. (Figure 15).

4) To the elevate urban highways (Figure 8), this proposed approach has great advantage in extracting work. Although the shape of them is complex, its edge has also been detected, especially the overlapping part(Figure 16).

5. CONCLUDING REMARKS

The results of research indicate that, the method mentioned in this paper has a good effect on the extraction work of the road information in modern cities, especially on the elevate highways that are obvious in modern cities. The appearances of elevate highways now are getting more and more complex, the centre section of this which is composed of many surrounding roads overlapping each other whose curvature are larger than general ones. Considering the aspect of the uniformity of grey value on road, we group the edge points of road again in the same supported region, which can realize the elevate highways exactly. With the rapid development of city and the complex of the road, traditional methods for extraction haven't satisfied for all the demands of the urban development, so an improved one in this paper has been proposed in view of the existed problems. But some roads can't be extracted correctly for the deficiency of the image quality and algorithm. Moreover, a few distances from the original roads appeared in some road crossings, which should be do more researches on it.

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