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A Semi-Automatic Extraction Algorithm of Strip Road from High Resolution Remote Sensing Image

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Abstract: *As the basic geographic information, road network recognition and accurate positioning have far-reaching significance for image understanding, GIS data acquisition, mapping and other target reference. How to extract road information from remote sensing image is an important research direction in recent years. In this paper, a semi-automatic road extraction algorithm based on variable bandwidth template for high-resolution remote sensing image is proposed, which can automatically change the width of the template according to the change of road surface, and better adapt to the change of road surface width. It is verified by the multispectral images of worldview-2, which shows that the algorithm can greatly reduce the amount of manual intervention and improve the accuracy and efficiency of the road.*

Keywords: *Semiautomatic Extraction of Roads, Variable Bandwidth, Template Matching, High-Resolution Remotely Sensed Imagery*

1. Introdution

Remote sensing is a modern technology to collect land surface information and detect its dynamic changes. Since the beginning of the 21st century, remote sensing technology has been widely used with the rapid development of remote sensing technology [1,2]. The number of remote sensing images obtained by space shuttle and various satellite systems has increased greatly, and the spatial resolution, spectral resolution and temporal resolution have also been improved, which provides a rich data source for obtaining the spatial geographic information of digital earth [3]. Therefore, how to explain the meaning of the spatial information and transform the original data into information that people can understand become the key to deal with the massive information. In terms of image interpretation, we need to move from primary image processing technology and visual interpretation of remote sensing images to understanding the meaning of remote sensing images, so as to meet the growing needs of social development [4-6]. Road network is an important basic geographic information, and the extraction of road features has become an important issue. Its recognition and accurate positioning are of far-reaching significance to the updating of GIS database, image understanding, mapping and other target reference [7].

It is an important way to obtain the information of the earth surface by using remote sensing image. The amount of remote sensing image data is large, how to quickly and accurately extract the required information from remote sensing image has become the current research direction. Among them, road extraction from remote sensing image is a research hotspot and difficulty. Domestic and foreign research in this area has a history of more than 30 years, and there have been many theoretical and technological innovations. Some scientific research institutions, such as Institute of remote sensing, Chinese Academy of Sciences, Institute of Surveying and mapping, Peking University, Wuhan University, University of national defense science and technology, and University of information engineering, have done a lot of analysis and Research on this. According to the degree of automation, remote sensing road extraction methods can be divided into semi-automatic extraction and automatic extraction [8,9]. Although there is no breakthrough in the field of full automation at home and abroad, it has achieved the goal of half automation. There are still great progress in the solution of automation, and some preliminary road extraction systems (such as the remote sensing road extraction system of Peking University)[10-12] have emerged. These work still need to be further expanded to achieve better functions and universality. The current research mainly uses spectral, texture and other features to extract roads through semi-automatic or automatic methods.

Road extraction by template matching is a quite important research area among various human–computer interactive semiautomatic extraction algorithms. There are many researches about this area [13-15]. Mckeown et al. [16] used the model to extract both road surface and edge information and build a coordinating system. They also finally obtained the road extracted based on the extracted road surface and edge. Gruen et al. [17] used the combination of LSB (Least Squares B-spline) and Snakes, i.e., LSB-Snakes, to extract the linear features of roads. They also extracted the road semi-automatically with dynamic programming algorithm. Parks et al. [18] acquired the road centerline seed points to generate a road cross section at first. Then, the template was matched with the reference one by rotating it, the road direction was computed, and a good matching result was achieved based on ideal road surface. Shukla et al. [19] acquired the edge information of the entire HSRRS imagery with a canny edge detection operator, and then the road was tracked based on the known seed points and initial direction. They acquired a candidate road when the stopping criterion was met. Then, they continued to determine the tracking direction of the seed points for the subsequent tracking process, and the step was iterated until the extraction of the entire road was completed. Lin et al. [20] took full advantage of road markings to raise the least squares image matching method based on the road marking template. They also generated a T-type or multiple-cross-type template according to the distribution of road markings, and the extraction precision of the classified road was improved by making the best of the spectral and textural features of road markings. Thus far, template matching has been considered as the most practical method among all the existing semiautomatic extraction algorithms. However, it still has some limitations, e.g., selection of road seed points, adaptability to change in road width, and effect of the shadows casted by the surrounding trees and vehicle. This study intends to explore the algorithm in selecting seed points and initializing road template based on the spectral and geometrical features of high resolution road image, and a self-adaptive variable bandwidth template matching algorithm is raised to extract the roads from HSRRS images.

The rest of this paper is organized as follows. Section 2 describes the road extraction algorithm. Section 3 presents the road extraction experiments. Section 4 discusses the results of experiments. The last section concludes the paper.

2. Road Extraction Algorithm

The radiation, geometrical, and contextual features are used most frequently in the road extraction algorithm based on template matching. In semiautomatic road tracking algorithm, the road must be initialized. Thus, single, two, or more seed points should be entered manually to determine the initial position, width, and direction of roads. The quantity of input seed points indicates the efficiency of the algorithm. However, the initialization precision of roads may decrease sharply if the quantity is small. Nearly no existing template matching algorithms have considered the effect of road width variation (the dense trees and parked vehicles on both sides of the road may produce a 'road narrowing' effect in the view of spectral analysis from HSRRS images). To some extent, the change in road width may lead to a failure in road tracking, and the algorithm efficiency may be affected when the roads are in complex environment.

Therefore, this study raises a variable bandwidth template matching algorithm to extract roads. The algorithm needs only two seed points to complete road initialization and to start the semiautomatic tracking of a road.

In general, the initialization algorithm with a certain number of seed points selected manually is adopted to acquire road tracking direction θi, width W, and starting point o when the template matching approach is used to track the road, and the three parameters are used to generate different templates [21-22].

To select appropriate seed points, this study proposes a direction-line rotation-based detection method to acquire the initial parameters of the road. Direction line is a detection parameter based on local contextual structure information of a pixel, and it can be used to identify and classify HSRRS images. For example, the length–width ratio of the detected object can be used to distinguish roads from buildings. Alternatively, the results of direction lines along multiple directions are combined to form the shape index of a pixel, which can be used to depict internal structure of pixels of HSRRS images. The primary principle of the direction line to be used in detecting the contextual information of a pixel is presented in the Fig. 1.

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Fig. 1: Schematic diagram for direction line detecting context structure for a pixel

The figure shows that the direction line is in fact a line that radiates from a pixel point. It extends along a certain direction, and it can rotate 360 °to detect the structural information around the pixel. In this study, the direction line is set as follows:

1) In the direction along which the line extends, the line stops extending if it comes across any pixel B that whose grayscale changes sharply, that is,

$$P_A = G_A - G_B \tag{1}$$

Where GA refers to the pixel gray value of the origin A (this value refers to the sum of gray values in case of multiple bands images), GB denotes the gray value of the point B on the direction line that rotates by θi, and PA represents the difference between GA and GB. AB is extended continuously. The direction line stops extending when PA exceeds a certain gray threshold Pmax. At the moment, LAB means the length of the direction line AB at the rotating angle θi.

2) The direction line cannot extend without limits and should have a certain length. When the length of direction line LAB increases to a certain threshold value Lmax, it stops extending automatically.

When the rotating angle θi is changed, we can determine the length of the direction line at different angles. Therefore, the maximum detectable scope of the direction line is the spatial structure with origin A as center and Lmax as radius.

We can obtain the three road initialization parameters, i.e., initial direction of road θAB, road width WAB, and starting point o, with the aforementioned method by selecting two manual seed points.

3. Experiments

Visual Studio 2008 under Windows XP system is adopted to implement the semiautomatic road extraction algorithm based on the self-adaptive variable bandwidth template matching, and the experiment on the road extraction algorithm is made based on the WorldView-2 multispectral image and UCX aerial image.

The presented WorldView-2 image, which was taken in June 2013, covered a part of the Zhengding County of Shijiazhuang City, and the resolution was 2m. The image was clear and not covered by clouds. Classified roads and urban streets could be observed in the image. Running vehicles on the roads, trees standing on both roadsides, and shadows of trees could also be observed. Figs.2 and 3 show the extraction results of two typical roads.

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Fig. 2: Extraction for State Road

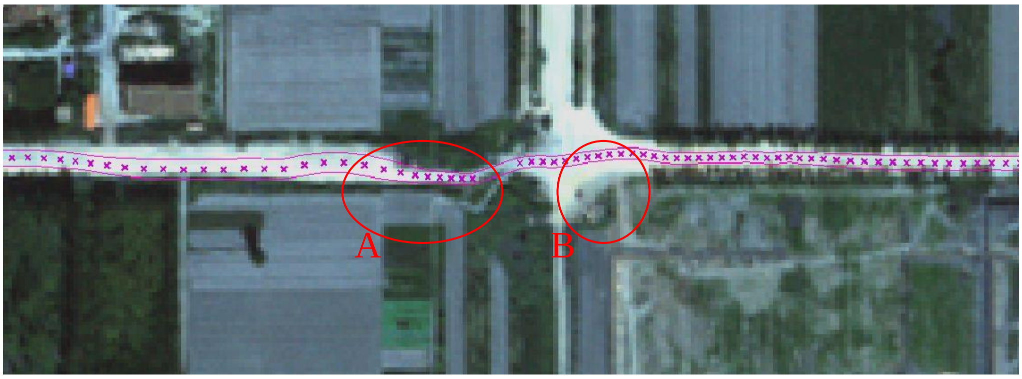

Fig. 3: Extraction for normal city street

Fig.2 shows the automatic extraction result of a classified road in suburb area of Zhengding County, whereas Fig.3 displays the extraction result of a complex road in downtown of Zhengding County. The red fork in the figures stands for the road central points and the lines above and under the central point are the extracted road boundaries. Fig.2 indicates that classified roads can be extracted well and form a strong contrast with the surrounding ground objects because of their clear texture and regular shape. The extracted central point is located in the center of the road, and the extracted road boundaries fit the actual road boundaries well. There is no need for manual intervention when starting tracking in Fig.2. The road is extracted automatically by our method when initial road values are determined. Fig.2 shows that the roads in Area B are obviously wider than those in Area A. The variable bandwidth algorithm in this study correctly extracts the evident changes in width. The road in Fig.3 is complicated because the road width varies by itself, and the plants on both sides of the road have a remarkable effect on the tracking. They also complicate the extraction of the road. The algorithm mentioned in this paper can adapt well to such a complex road. When the road seems to become narrow, the self-adaption function makes the template width decrease to adapt to the changes of road width, as shown in Area A in Fig.3. The road extraction algorithm may stop and need manual intervention (manual intervention is made once in Fig.3) when the road changes greatly and exceeds the gray threshold (Formula [5]), as shown in Area B.

4. Conclusion

In this paper, a semi-automatic road extraction algorithm based on variable bandwidth template for high-resolution remote sensing image is proposed, which can automatically change the width of the template according to the change of road surface, and better adapt to the change of road surface width. The main conclusions are as follows:

1) The starting position of the road is initialized by two man-made sites, and then the rectangular template is used to predict the best road point. At the same time, the width of the road is adjusted adaptively. According to the actual situation of the road, the width of the rectangular template is

increased or decreased, which improves the extraction ability of complex roads to a certain extent.

2) The main advantage of the algorithm is variable bandwidth, which can automatically change the width of the template according to the change of the road. Compared with the algorithm with fixed template width, the algorithm is more efficient, and can deal with the traffic congestion of roads with parking, trees and other situations

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