Road Information Extraction from High Resolution Remote Sensing Images Based on Threshold Segmentation and Mathematical Morphology

Hairong Ma, Xinwen Cheng, Xin Wang, Jinjin Yuan
Faculty of Information Engineering
China University of Geosciences
Wuhan, China

Abstract—**Extracting road information rapidly and efficiently from high resolution images is one of the research hotspots and difficulties in remote sensing. This paper studied road extraction from high resolution remote sensing images based on threshold segmentation and mathematical morphology. Information like road seed points and orientations didn't need to be given manually in this algorithm, which to some extent improved automation of road extraction. The extraction process can be expressed as follows: Firstly, remote sensing images were segmented into binary images containing road information through threshold way. Then mathematical morphology operations are used to process binary image, extracting road regions according to road morphological characteristics. Finally, road centerline and contour were extracted by exploiting relevant mathematical morphology operations, which was proved by numerous experiments.**

Keywords- High Resolution Remote Sensing; Road Extraction; Threshold Segmentation; Mathematical Morphology

I. Introduction

With the rapid development of remote sensing (RS) technique, the spatial resolution, temporal resolution and spectral resolution of the RS image improves accordingly, giving them such advantages as high real-time, broad coverage, rich ground information, etc. Obtaining object information from the high resolution RS image has become an important approach for spatial information updating, and has been widely applied in fields like national economy and defense technology construction. As an important component of fundamental geographic information, road network information has great application value in many fields, such as digital map update, spatial database establishment and update, urban construction design, etc. Therefore, how to extract road information efficiently and precisely has always been a hotspot in remote sensing field.

Since the 1970s, a lot of studies have been carried out on road extraction algorithm for the RS image [1]. According to the necessity of manual intervention, methods can be classified into two categories: semi-automatic and automatic road extraction methods. For example, Quam designed the road feature relevance based correlation tracker to trace and detect road. Gruen extracted road information successfully using dynamic programming [2]. Miriam Amo, Femando Martinez, Margarita Torre proposed a regional competition method to extract road information [3]. Fischler utilized graph-search to automatically trace and extract road information from low resolution images [4]. Hinz succeeded in using road automatic extraction based on geometric and statistical model method [5]. Trinder J.C put forward road automatic extraction method based on the extraction of parallel lines [6].

This paper studied mathematical morphology based road information extraction from high resolution RS images. Mathematical morphology is a novel digital image processing method with advantages of simple arithmetic, parallel processing ability, fast speed and ease of implementation, etc, which studies morphological structure features and fast parallel processing of digital images, Therefore, it gets widespread application in digital image processing and pattern recognition [7]. It is based on the idea that certain forms of structural elements are used to measure and extract corresponding shapes in order to analyze and recognize images. Mathematical morphology is mathematically based on set theory, through which image data can be optimized, their basic shape features be kept and irrelevant structures be rejected.

II. Fundamentals of Mathematical Morphology and Its Feasibility Analysis in Road Extraction from RS Images

Mathematical morphology was introduced into image processing by Matheron and Serra in 1964 [8], which was used to detect geometrical shapes in binary images. It's a morphology based mathematical tool used to analyze shapes and structures of images, and it has played an increasingly important role in image filtering, segmentation, edge detection, etc. Morphologic algorithms on image processing were used in this paper are detailed in [9].

As a digital image processing method, mathematical morphology has such advantages as simplicity in form, parallelism of calculation, compared with other linear methods, having great advantages. Moreover, morphological algorithm also has strong application in image filtering, segmentation, particle analysis, target thinning, etc.

(1) Morphological filter

The morphological open-close operation is dual, with its open and close operations separately being used in the

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processing f peaks and valleys in gray image processing, small salt-pepper noise removing and blowhole noise filling in binary image. Usually, these two operations are also combined to form alternating filter, mixed filter and alternating mixed filter, which can eliminate interference information efficiently, and better keep geometric features of original image at the same time.

(2) Image segmentation

The motive of image segmentation is to segment road information away from ambient noise for further processing. Mathematical morphology, is superior in analyzing and processing discrete objects with specific geometric shapes.

(3) Particle Analysis and Morphological Reconstruction

Morphological particle analysis is a method that analyzes particle sizes and shapes of discrete objects in digital images. Due to the impact of structural elements' size on basic operators of binary morphology, a set of growing structural elements can be applied to conduct open operation to images, and then a statistic analysis of the results are made, thus shape features and particle analysis of discrete objects in images can be obtained eventually.

III. THE ROADS EXTRACTION ALGORITHM AND EXPERIMENTS BASED ON THRESHOLD SEGMENTATION AND MATHEMATICAL MORPHOLOGY

According to the characteristics of mathematical morphology operation, a road extraction algorithm based on threshold segmentation and mathematical morphology was proposed. First remote sensing images were transformed into grayscale images, and threshold segmentation was done on grayscale images, aiming to separate road target information from non-road background information, next mathematical morphology operations were utilized to remove noise, and then the road region based on the morphological characteristics of the road was extracted, finally, morphological operations were used to extract road centerline and edge information. In this paper, all experiments were conducted on Matlab7.8 platform, some of the operations from Toolbox functions and others written by myself.

Figure 1. Original image

3.1 Image graying

In this paper, graying processing of the target image was conducted with weighted average method. Different weight values were given to R, G, B respectively according to the importance of these three indicators. Empirical image graying formula was as

$$R = G = B = \left(0.229R + 0.587G + 0.114B\right) \quad (1)$$

Formula (1) was used to transform the original image (Fig. 1) into gray and the result was shown in Fig. 2.

Figure 2. Grey image

3.2 Threshold segmentation

Image threshold processing plays an important role in image segmentation. In this paper, the OSTU method was used to calculate the threshold value [10]. The segmentation result, as shown in Fig. 3, indicated that the road information was separated from the background information.

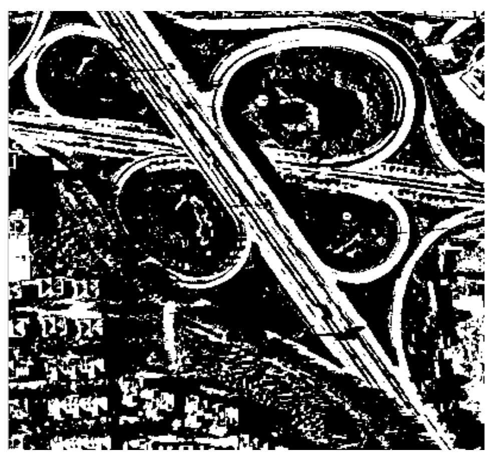

Figure 3. Threshold segmentation of Figure. 2

3.3 Noise removal

Fig.3 indicated that binary images after threshold segmentation contained a lot of noise: similar road information, such as residential areas may mix up with roads, even stick together, furthermore, the shadows of roadside trees made the extracted road broken. Road details in high resolution remote sensing image are so clear that vehicles and lane lines on road made the extracted road exist holes and elongated strip cracks incoherence. However, there were still a large amount of small noise in background region. By designing the morphological operators reasonably and series of morphological transformations non-road information could be reduced and removed.

(1) Small noise filtering.

States of roads in remote sensing image generally have two kinds: one is extended to the edge of the image, another is intersected with other roads. Dependent on this property, the principle of morphological remodeling was used to clear non-road object separated from the image boundary. Using binary image as masks, mark image f_m is defined as

$$f_m = \begin{cases} f(x,y) & if\,(x,y) \text{ is on the boundary of } f \\ 0 & if\,(x,y) \text{ isn't on the boundary of } f \end{cases} \quad (2)$$

Figure 4. Extraction result of small noise

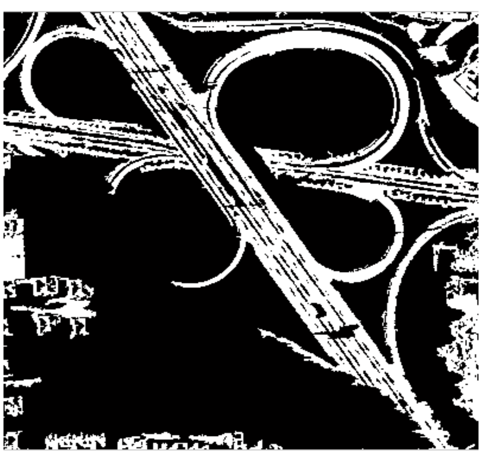

Figure 5. The result of minor noise removal

Results of noise extraction and noise removal are shown in Fig. 4 and Fig. 5 respectively. Fig. 5 indicated that non-road noise had been largely removed after this operation. There was no non-road area and road area adhesion phenomenon and only a few non-road noises adhering to image edge remained. In section 3.4 the morphological characteristics of the road were used to remove non-road noise adhering to image edge.

(2) Cracks and Holes Noise Filling

It could be seen from Fig. 5 that there were lots of hole noises and crack noises caused by vehicles, pedestrians and lane lines on the road. Firstly, eight neighborhood expansion operations were done to each pixel in the image, after which cracks were connected and holes was filled, then mathematical morphology method was used to eliminate larger holes in road area and non-road area. As shown in Fig. 6, after a series of morphological operations, road and non-road distribute regionally on the whole, providing good data for road area extraction in the next step.

Figure 6. The result noise filling

3.4 Roads area extraction

According to the geometric characteristics of roads in high resolution remote sensing images, it can be obtained that: roads in the image generally present a certain width of strip, large length-width ratio; but non-road areas, such as top of buildings, parking lots, etc. are similar to road ones in gray scale, usually with small aspect ratio. Therefore the ratio of each region's area and perimeter could be used to distinguish the road and non-road areas, in order to unify the units of area and perimeter, the ratio of area of square root to perimeter was taken to judge whether the target area in the image is road area or not.

(1) The total number of pixels S and boundary pixels C of the target area was counted up. And then the ratio of area of square root to perimeter t was calculated by $t = \sqrt{S} / C$.

(2) In addition, t from smallest to largest to be series was arranged by size to be a series $t1$, and artificial was used to determine the number of road area in the image n, Only areas which made up top n values of $t1$ was kept, then road areas

could be obtained. The application result using this road extraction was shown in Fig. 7.

Figure 7. The result of road extraction

Fig. 7 shows that this method could extract a variety of linear roads in the image, but the road under the influence of roadside trees shadow or other shadows cannot be extracted exactly. The existence of shadow greatly affects the accuracy of the road extraction. As a result, in order to improve the accuracy of road extraction, efforts should be paid on removing the influence of large shadow from roadside trees or buildings on the road.

3.5 Reprocessing

After the completion of the extraction of road area, according to the different application requirements of further processing to the extracted results, extraction of contour lines and road centerlines of road areas can be applied widely. For example, when the roads were damaged by geological disasters, floods or other natural disasters, the conditions of the road damage can be evaluated by extracting the contour lines. In building road networks or navigation, the extraction of road centre line is indispensible.

(1) Contour extraction.

Contour following operator was used to track and mark the outline of the road area. Contour following operator can quickly locate the target areas in binary image contour pixels, and record the corresponding pixel coordinates. To show the effect of the contour line extraction in comparison, the extracted contour lines were overlapped on grayscale images with white color, as shown in Fig. 8.

(2) Road centerline extraction.

In this paper skeletal methodology was used to extract the road centerline. Due to the effect of cars, lane lines on the road and the shadow of roadside trees or buildings, the extraction road area was often not smooth. Consequently, in the skeletal process, extracted centerlines may have short "burr" or parasitic components, thus the results of bone mineralization should be trimmed to remove burrs, function "endpoints" was used to achieve this process, this function will automatically calculate and remove endpoints, get the road centerline. To show the effect of road centerline in comparison, the extracted centerline was overlapped on grayscale images with white color, as shown in Fig. 9.

Figure 8. The result of road contour line and gray image overlay

Figure 9. The result of road centerline and gray image overlay

IV. THE EXPERIMENT RESULTS

Many experiments were done to demonstrate the effectiveness and broad applicability of this road extraction method in high resolution remote sensing. Experiments had shown that this road extraction method can be well used in the extraction of main road, narrow track intersected with the main road (Fig. 10), paralleled narrow roads (Fig. 11) and main roads crossed with each other (Fig. 12, Fig. 13). The extraction results were not affected by noise of cars and lane ropes, but the shadows of huge buildings and trees along the road could make road edges indented (Fig. 10), or exist fracture zones on the road (Fig. 12), more seriously, make the road unable to be recognized (Fig. 7). The existence of shadows greatly affect the accuracy of the road extraction, thus how to remove the influence of large shadow from roadside trees or buildings on the road is one focus of future research.

(1) Original image (2) The result of road area extraction

Figure 10. Road extraction experiment (one)

(1) Original image (2) The result of road area extraction

Figure 11. . Road extraction experiment (two)

(1) Original image (2) The result of road area extraction

Figure 12. Road extraction experiment (three)

(1) Original image (2) The result of road area extraction

Figure 13. Road extraction experiment (four)

V. CONCLUSION

Extracting road information was achieved according to the characteristics of roads in high resolution remote sensing images using threshold segmentation and mathematical morphology. This method used threshold segmentation to carry on binary processing for gray image firstly, then mathematical morphology method was utilized to remove noise, then road was extracted according to the features of the road shape. Finally, road information was extracted (such as centerline and contour) through morphological algorithm. Without using artificial seed points of road, the method realized the automatic extraction of roads to a certain extent.

Based on the geometric characteristics of road, the element of the morphological structure in the processing parts was chosen by repeated experiments. Thereby, how to choose the element of the morphological structure efficiently according to the geometric characteristics of surface features will be one focus of the ongoing study.

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