Road Extraction from Remote Sensing Image Based on Multi-resolution Analysis

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Abstract: In the paper, we present an approach of multi-resolution analysis to extract road information from high resolution imagery. Firstly, high resolution imagery is divided into a series of different resolution images. According to the representation characteristics of roads at different resolution, we analyze roads' geometrical, radiometric, and topological attributes and carry out a variety of processes such as image enhancement, edge detection ,road finding ,tracking and linking. Then most of main roads at different resolution are gradually extracted. After that, the internal relationship between the same roads at different resolution is set up. All extracted roads are generally normalized into initial resolution to be performed data fusion for eliminating wrong roads and adding miss ones. Thus main roads are correctly extracted. Finally, an example of test is presented in which shows that the exploratory approach is applicable to high resolution road extraction but needs further improvements.

Key Words: Road extraction, Remote sensing image, Multi-resolution analysis

1. INTRODUCTION

In recent years, study on road extraction from high spatial resolution imagery has become a heated research subject in the domain of remote sensing due to its apprehensive application like city planning, management, cartography and GIS update, etc. Correspondingly, many ways of road extraction have been proposed and they are quite different due to the differences in strategies, type and resolution of input images, experiment configurations, ways of processing and general assumptions, etc. Judging from the view of automation, there are mainly two types, i.e. semi-automatic and automatic road extraction from images including aerial photos and satellite images(Mena,2003). In general for the second type, there have been intensive efforts to extract roads automatically in the last decades, The recent and later trends to have satellite images with a very high spatial resolution(less than 1 meter) has rebooted the interest of road extraction. The increased resolution enables a more accurate localization of the road sides and centerlines. Therefore, the automatic detection of roads especially from high resolution imagery is a very important problem and also a challenging topic because of the mass data, complex texture and redundant details of high spatial resolution image.

In the paper, the basic characteristics of roads in remote sensing image are introduced. Considering the characteristic that a road has different representation on images at different resolution. Therefore, we are attempt to combine their respective characteristics and present an approach of multi-resolution analysis to extract roads from high spatial resolution imagery, which is decomposed into a series of different resolution images. We perform road extraction at different resolution. Then the extraction results of different resolution image are fused at the initial resolution. This way overcomes the shortage of extraction in an individual resolution image.

2. ROAD MODEL for MULTI-RESOLUTION ANALYSIS

In order to recognize and localize objects, we must possess a model of objects of interest and of its appearance in image. It is well known that different types and different resolutions of image include different road characteristics. Generally, in low resolution images, roads are expressed as a single line on which gray value distribution is symmetrical. While in mid or high spatial resolution images, roads are represented as a surface with constant width and gray values of neighboring pixels change fast because of the effect of cars, trees, buildings

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and road marks . Besides, local change of road curvature is supposed to vary slowly. Road network is an important characteristic which can be obviously seen at different resolution.

Our road model is based on the following hypothesis: (1) Gray value of neighboring road pixels changes fast, but global distribution is symmetrical.. The width of a road and its curvature vary slowly;(2)The texture enclosed by the road edges is rather homogeneous despite that there exist local disturbance such as shadows cast by adjacent buildings, trees or cars;(3) There exist connectivity between roads which forms road network. In a word, our road model mainly consider the geometric, radiometric and topologic characteristics at different resolution. Geometry captures such descriptions as location, shape and size of road. Radiometry deals with the gray value. Topology are created by the road network.

3. ROAD EXTRACTION BASED on MULTI-RESOLUTION ANALYSIS

3.1. Spatial resolution effect on ground object recognition

Spatial resolution of a image has a strong influence on the representation of both roads and other objects.This implies that many details recognizable at high resolution become unclear and finally disappear when the image resolution gets lower.Low-resolution methods are able to locate many roads using simple road models but not accurate. High-resolution methods have access to much more information and can investigate roads in detail. However, since other objects in image are also represented with many details, the task of road finding requires complicated methods for the abstraction of these details. In general, a multi-resolution approach offers an appropriate framework for automatic road extraction. Since road extraction in high resolution is difficult but reliable. It is a good idea to guide it with results of road detection in low resolution which needs less efforts at the cost of probable mistakes.

3.2. Multi-resolution image creation

In general, there are two ways of getting multi-resolution images. One is from a single remote sensor or variable sensors. The other is to use wavelet transform or pyramid analysis,. Compared with the former way, the latter one is easy and convenient. In the paper, we take the way of pyramidal decomposition to get images with different resolution from high spatial resolution satellite image.

3.3.Road recognition from multi-resolution images

The flow chart of road extraction by multi-resolution analysis is as in fig1.

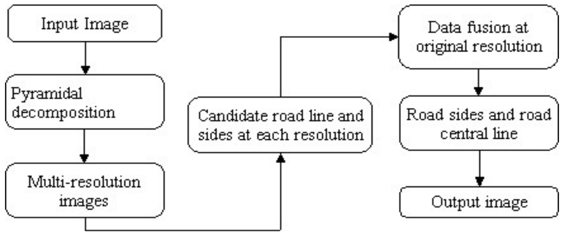

Fig1: Flow chart of road extraction from high spatial resolution based on multi-resolution analysis

For a high spatial resolution image, it is decomposed into a series of images with different resolution by ways of pyramidal decomposition. At different resolution, different ways are taken to extract candidate road lines or road sides. Then the extracted results are fused to form true road sides or centerlines at initial resolution Of course, there are still many scattered road lines and sides or conflicting ones. In order to ensure accurate position, only results from initial image are accepted. The low and mid resolution results serve as a guidance for eliminating false sides or lines and adding missed ones. Finally, a graph including road sides and centerlines is finished.

3.3.1.Low resolution road extraction

Fig2 shows the flow chart of low resolution road extraction.

At low resolution, roads are expressed as line with a width of

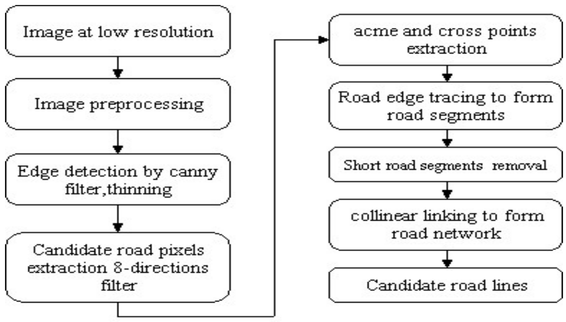

Fig2: Low resolution road extraction

about 1-3 pixels. Thus roads are modeled as lines. Our goal is to extract the center lines of the roads with a width of one pixel. Normally before extraction, it is necessary to preprocess(median filter) the input image for later processing Then road edge detection is carried out. There are many edge detections filters, such as Robert, Sobel,Prewitt,Canny,etc.Through comparison, we decide to use Canny filter to extract edges. Subsequently, a thinning operation is applied (Rosenfield,1976), yielding one pixel wide edges.

In the next step, we take an 8-directions filter(Yan Rianto,2002) to detect candidate road edge pixels. Having done the above work, we get a binary image in which the gray value of candidate road pixel is 1, others is zero. Then we scan the image and find all acme and cross points. After that, road edge tracing is performed to obtain road segments. When all road edge points are scanned, we get most of road segments. They are not really road lines. Then we must have a strategy to link adjacent road segments. The strategy we use is presented by Zhao(2001). When all road segments are examined, the work of collinear linking is finished .
The graph of road line is produced.

3.3.2.Mid-high resolution road extraction

The flow chart of mid-high resolution road extraction is shown in fig3.

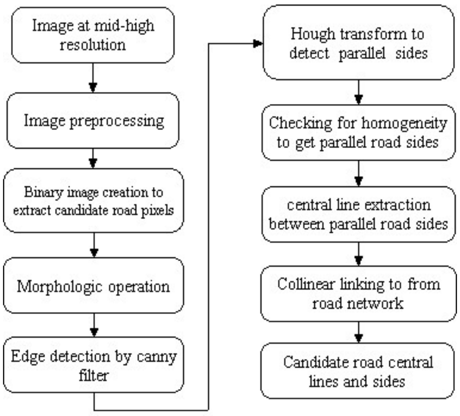

Fig3: mid-high resolution road extraction

In mid-high resolution image, roads are expressed as a surface with parallel boundaries and a homogeneous gray value in its local area. Of course, there are many disturbances on road surface. The homogeneity criteria is violated by shadows or occlusion caused by houses or trees. Despite that great gray change often occurs, the global gray value is in a certain range. Therefore, we firstly start with a simple image segmentation based on gray value threshold by way of ISODATA classification. The candidate road regions are selected. Then we get a binary road image. Next, we take a series of morphologic operation (dilate ,erode) to exclude isolated pixels on the road surface. After that, canny filter is used to obtain candidate road edges. According to its anti-parallel linear characteristic, we divide the binary edge image into a small image areas(the number of areas is adaptive to image size) with a size of 32*32. and use Hough transform to detect parallel road sides.
In each area, Once finding two parallel lines, we examine the region between the parallel lines while using a symbolic labeling of pixels as the local property criterion and search for maximal sets of pixels whose labels are consistent and gray change is slow are taken as candidate road sides. Immediately, the corresponding central road segment is extracted. When all areas are examined, we obtain all parallel road sides and its central road segments.

In the following step, we will use the above mentioned way of collinear linking to link central road segments.Then the road network is formed and the graph of road surface is also produced.

3.4.Combination of the different resolution road extraction

As mentioned above, both the presented ways of low and mid-high resolution road extraction have advantages and disadvantages. Regardless of the quality of extracted road at any single resolution, it will usually fail in at least some part of the image. In order to increase their quality, we combine them to eliminate the risk that some roads extracted at one of the resolution levels might be lost at others. The strategy of combination we use is presented by (Heipke,1995). All extracted roads at different resolution are generally normalized into initial resolution and then overlapped to form a layer including all extracted information. If there are central lines between parallel sides, then we accept the parallel sides. If only exist central line and the corresponding lines at different resolution are firmly similar, then we accept the line and draw its parallel sides based on the adjacent road sides. Else if no much relevance exist between the corresponding lines at different resolution, we will consider the context information to decide whether to accept or to reject the line. Besides, visual inspection and manual operation is also used in order to ensure accurate positioning of the selected road lines and parallel sides.

4. EXPERIMENT

In order to test the performance of the suggested approach, we have applied it to real Ikonos panchromatic imager with a resolution of 1m and the size of 512*512,which is of a small district of Peking University,,China.We firstly decomposed it twice by pyramidal decomposition. Then we get three different resolution images,as shown in fig4(a,b,c). Using the mentioned ways of multi-resolution analysis, we get extracted results shown in fig5(a,b,c). Finally, we combine them and take some manual operation to obtain the final extracted roads.(fing6).

5. CONCLUSIONS

In the paper, we analyze the characteristics of roads at different resolution and present an approach of multi-resolution analysis to extract road information from high resolution imagery By visual inspection, the offset between the real roads and the extracted ones are very small. Judging from the preliminary test results, we think our approach can extract most of main roads and the results is satisfactory despite that some wrong and incomplete roads segments are extracted and manual operation are needed sometimes. In future , we will focus on improving the flexibility and automation of the approach and presenting ways of data fusion based on road features. Besides, ways of quantitatively evaluating the extraction results will be further studied.

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a:Initial image

b:Decomposed image by factor 2

c:Decomposed image by factor 4

Fig4: Initial image and its decomposed images

a:Road extraction form Initial image

b:Road extraction from image decomposed by factor 2

c:Road extraction from image decomposed by factor 4

Fig5: Road extraction from different resolution image

Fig6: The final extracted road sides and central lines