Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.

Automated Extraction of Control Points for High Spatial Resolution Satellite Images

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KEY WORDS: Control Points, High Resolution, Satellite, Road Intersection

ABSTRACT: As IKONOS satellite with 1-m resolution camera has been lunched in 1999, mapping using space-borne images will be a hot issue in computer vision area and photogrammetry. It is obvious that one of the great challenges to process the high spatial resolution satellite images will be the geometric correction practice. Conventionally, the positioning of the image control points is manually performed by a labor- intensive and time-consuming procedure. Furthermore, due to the abundant image contents, high spatial resolution satellite image would have plenty of the qualified control points. As a result, the manual identification and positioning of control points will become even more inefficient and unbearable. Therefore, the main objective of this study propose to develop an automated image processing technique to extract the control points for the high spatial resolution satellite images. Among numerous spatial features, this study considers even widespread road intersection the main target to perform the control point extraction. The proposed method consists of two parts. The first part is "Road extraction" consisting of four steps image-processing algorithm and the second part is "Spot of Road Intersection Searching" consisting of two steps image-processing algorithm. A series of high spatial resolution satellite images are used to test the proposed method. The preliminary results shows that the proposed image processing approach has the potential to automatically position the control points in the high spatial resolution satellite image.

1.INTORDUCTION

IKONOS, which is the first commercial 1-m resolution satellite, has been successfully launched in 1999 and also several 1-m resolution satellites are being launched within few years. The availability of such high-resolution satellite images may change the mapping, photogrammetry and remote sensing world. Because the shortcomings of airborne photogrammetry, such as small coverage, difficulties in periodical acquisition may be overcome and many objects that were not identifiable in low-resolution (10-30m) may be detect in high-resolution images. Therefore, high-resolution, after being image geometric corrected, can be combined with various other thematic maps, air orthography or any other geographic systems. It will become one of the major sources of space data. The project chooses road intersections as the controlling point for satellite images. The reason is that high-resolution satellite image contains resourceful transportation information. The way these intersections distribute meets the basic need of image controlling points: even distribution and abundance. As a result, I propose two perspectives to dig into the problems: "Road extraction" and "Spot of Road Intersection Searching". Extracting roads is so far done using high-resolution airborne images or low-resolution satellites images for highways or wide roads. There have been intensive efforts to detect roads from low-resolution satellite and low-resolution airborne images. Fischler tried to detect road and "line-like" structures appearing in low-resolution (10-20m) aerial imagery (Fischler et al, 1981),.Nathan introduced an estimator that was robust and statistically efficient to detect straight or circular pieces of roads in noisy low-resolution aerial images (Nathan et al, 1997). Donald proposed an approach for tracking roads from satellite images (Donald and Judynek, 1996). Zlotnick described a road finding system based in the road hypotheses (Zlotnick, 1993). However, because low-resolution images were assumed in these methods, roads were represented as a "line-like" structure. Road can be defined as long "line-like" objects at least in low-resolution satellites images. But, roads are not line anymore in 1-m resolution images. Rather, roads are ideally long "rectangular-like" objects. Indeed, as shown in figure 6, it is difficult to detect roads by extracting long lines from images. In this study, roads extracting problem may be regarded as finding rectangular-like regions. But, there are always other objects such as tree beside of roads, shadows of buildings and lots of cars existing on roads. Also, the brightness of roads of satellite images is usually dark if they are covered by asphalt and bright if they are covered by cement. For this reason, interactive terminal is necessary in process of extracting roads. The proposed image-processing algorithm consists of four steps about "Road Extraction", as follows: (1) Meaningful Regions Segmentation (2) Redundant Noise Reducing (3) Road-region Recognizing (4) The Pattern of Roads Refining. After road extracting, the road intersections is become quite apparent. However, after the road is chosen, the image often resulted in an area. We must find the exact spot of road crossing point in the area before image controlling points show up. Then we can move on to image registration of satellite image. The proposed image-processing algorithm consists of two steps about "Spot of Road Intersection Searching", as follows: (1) Frameworks of Road-Region Extraction (2) Spot of Road Intersection Detecting.

In Section 2, the algorithm about "Road Extraction" will be described. In Section 3, the algorithm about "Spot of Road Intersection Searching" will be described. In Section 4, the result will be reported. The current problem and the future work will be described in Section 5.

2.ROAD EXTRACTION

First, utilizing interactive Graphic User Interface to select the road intersections roughly and choosing the brightness of roads is either dark or bright. Then, generating sub-images with road intersections and the characteristics that roads belong to different and unceasing region. For this result, we can focus small scope on road intersections and initial the brightness of roads and make the difficulty of extracting roads depressed. And, the proposed scheme of "Road Extraction" includes following steps: (1) Meaningful Regions Segmentation (2) Redundant Noise Reducing (3) Road-region Recognizing (4) The Pattern of Roads Refined.

2.1 MEANINGFUL REGIONS SEGMENTATION

The aim of this step is to segment sub-images into meaningful regions that are large-scale inhomogeneous portions in a sub-image. It is obvious that roads are first fit in with inhomogeneous portion of 1m-resolution image because it width is usually insufficient 20pixels. Therefore, we develop appropriate method for segmenting meaningful regions from image after we initially decided the brightness of road. We design a template to detect inhomogeneous regions. There are two arguments of template must be defined at first. One of them is the size of template presented by NxN, another is the numerical value of every element. As a result of road width is less than 20pixels, we assume that N is larger than 21pixels and modify the numerical value of elements, presented by w(i,j), with (eq.1).

$$\begin{cases} w(i,j) = -1/N^2 \;;\; i,j = 0 \sim N \text{ and } \; i = j \neq N/2 \\ w(N/2+1, N/2+1) = 2 - 1/N^2 \end{cases} \qquad \text{(eq.1)}$$

We are able to find out that roads have been segmented into image after convolution because the template size is larger than road width. Moreover, we choose the dark of bright portion of image to be meaningful regions, which are marked for gray-level 255, based on the initial argument of GUI at last. The result will be shown in figure 1a,b and c.

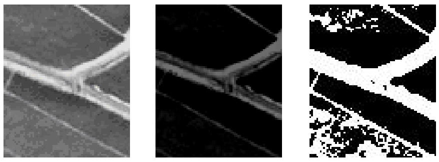

Figure 1. (a) A Sub-image of IKONOS (b) Illustration of the result after convolution (c) Illustration of the result after image-processing Meaningful Regions Segmentation

2.2 REDUNDENT NOISE REDUCE

The purpose of this step is to reduce the redundant noise of the image with meaningful regions. As show in figure 2b, there are plenty of regions with small area. It would be redundancy when utilizing meaningful regions to describe roads. Thus, we need to code every region and compute the measure of area at the same time. Next, setting up the threshold of region about area and adjusting the attribute of regions according to the threshold. As the area of a meaningful region is smaller than the threshold, we change the attribute of the region to meaningless. Similarly, a meaningless region would be changed attribute to meaningful if the area of it smaller than the threshold. The result will be shown in figure 2a and 2b.

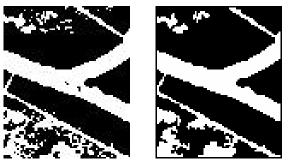

Figure 2. Illustration of the result after image-processing (a) Meaningful Regions Segmentation (b) Redundant Noise Reducing

2.3 ROAD-REGION RECOGNIZATION

The objective of this step is to recognize the mot probable region as road-region from all the meaningful regions. As given, it is addressed that we can focus small scope on road intersections in the sub-image with the characteristics that roads belong to different and unceasing region. Hence, there will be only one region to represent road.

If we assumed that the meaningful regions are all the parts of road, it is possible to use the core center for all regions to provide main road information for road-region recognizing. Therefore, we co-operate with erosion algorithm to find the road-region out. It consists of 3step.

(1) Compute all regions core center (Xc,Yc).

(2) If (Xc,Yc) is located on the any meaningful regions, we are determining the region is road-region. However, if there is no region satisfied the demand, processing the image with erosion and move on to step (3).

(3) Repeat step (1) and (2) until road-region is found out.

The result will be shown in figure 3a and 3b.

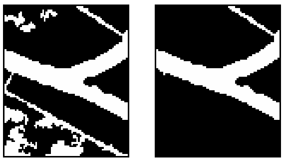

Figure 3. Illustration of the result after image-processing (a) Redundant Noise Reducing (b) Road-region Recognizing

2.4 THE PATTERN OF ROAD REFINING

The aim of this step is to refine the pattern of road-region that contains some errors caused by the shelter.

As show in figure 4b. The over- or under- segmentation is well known problem of the algorithm. Because roads maybe too close to other similar objects in space and they may also be affected by large buildings, the result may be flaw and the mistaken information may lead to changes of road pattern. Thus, identifying range of the road-region is the pending problem must be overcome. In this study, we attempt utilizing simple and effective rules consisted of our knowledge to handle the trouble. Rules can be partitioned into two parts, A and B. Sequences of PART(A) algorithm are listed as follows: First, utilizing Sobel-Edge-Detector to extract the outline of road-region. Second, make the mistaken information separated form road-regions, as show in figure 4a and 4b. Third, cut the redundancy off and then extract edge of road-region again. Fourth, adding the new outline to road-region. The result is shown as figure 4b.

Then, Sequences of PART(B) algorithm are similarly listed as follows: First, utilizing Sobel-Edge-Detector to extract the outline of new road-region generated by PART(A). Second, make the mistaken information separated form the remaining of image except road-regions, as show in figure 6a and 6b. Third, cut the redundancy off and then extract edge of road-region again. Fourth, adding the new outline to road-region. The Final result is shown as figure 4c.

Figure 4. Illustration of the result after image-processing (a) Road-region Recognizing (b) PART(A) of The Pattern of Roads Refining (c) PART(B) of The Pattern of Roads Refining

3. SPOT OF ROAD INTERSECTION SEARCHING

However, a complete road-region can't directly provide the information about road intersections. Generally, we have to extract the frameworks of road-region and form judgments upon the crossing points of the frameworks, and then we can gather the information of crossing points. Therefore, when searching road intersection information, we have to extract road-region frameworks and to look for the crossing points. At the same time, we compute the center of road-region (Xc,Yc). In the end, we can find out the crossing points of road intersection and output image control points because of the constraint demanded that road intersection must be nearby the (Xc,Yc) around 10 pixels. The result is shown in figure 5.

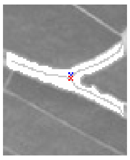

Figure 5. Illustration of the final result after image-processing "Spot of Road Intersection Searching"

4.EXPERIMANTAL RESULTS

The experimental includes tests of the proposed algorithm for automated extracting control points of high-resolution satellite images. The image was sampled in Oct. 09, 2001 with a 53.70793° elevation angle and 142.6061° azimuth. The image covers the city of Tai-Chung in central of Taiwan with an area of 11km*11km as shown in figure 6. We select total number of 16 cases for testing. Figure 7 will sequentially display results. And we are given that the result if coincided with manual in every case with the validity of statistical estimation.

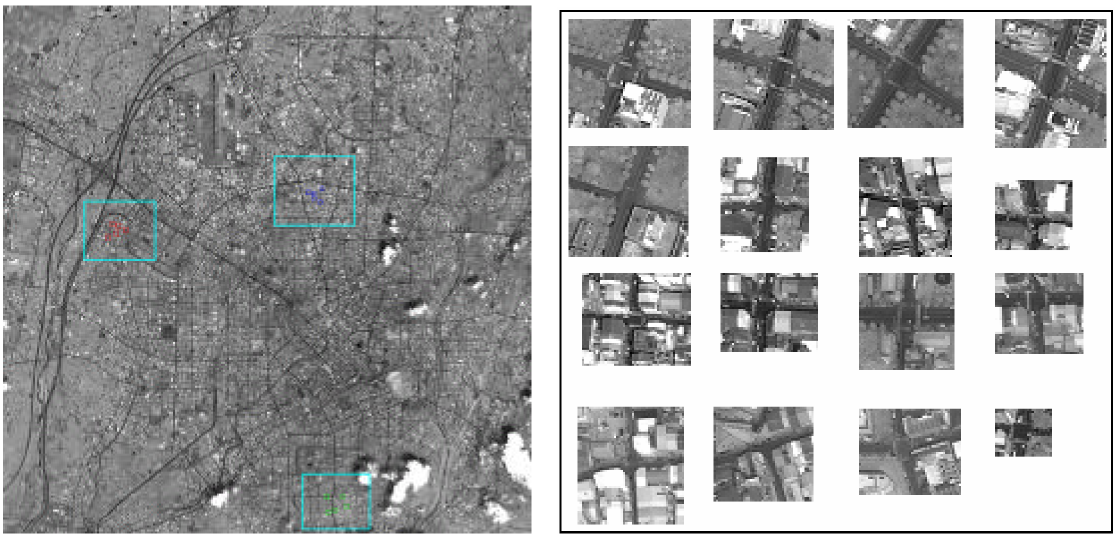

Figure 6. The Test image (Left-side is source date and Right-side is sub-images)

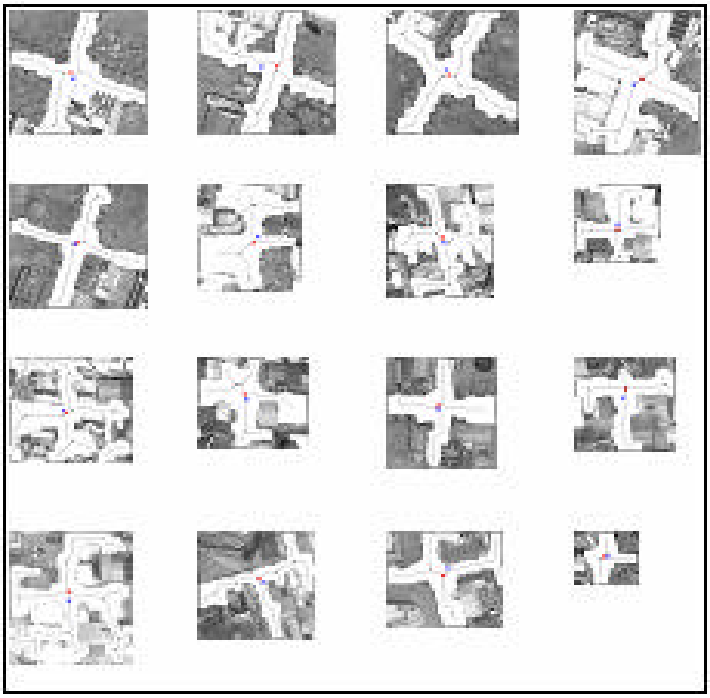

Figure 7. Automatically extraction of controlling points in the testing areas.

5. CONCLUSION

The 16 tested areas may automatically result in the control points. With precise examination, all areas passed the test except case 2, which means that the control points coincide with manual obviously even under the influence of buildings. We can conclude that even though some roads of the tested areas are not extracted completely, we can obtain the same result with that of manual judgment. Therefore, the automatic extracting of control points in this study is proven to work well and precisely. After re-examining tested area 2, road intersection is indeed extracted. But during the process, we chose the wrong position for the output value of control points. It explains that there is room to improve in the way control points are determined. If the problem can be handled properly, the result of extracting control points automatically will be more satisfactory.

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