Road Extraction Based on Watershed Segmentation for High Resolution Satellite Images

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ABSTRACT: Recently, the spatial resolution of earth observation satellites is significantly increased to a few meters. Such high spatial resolution images definitely will provide lots of information for detail-thirsty remote sensing users. However, it is more difficult to develop automated image algorithms for automated image feature extraction and pattern recognition. In this study, we propose a two-stage procedure to extract road information\from high resolution satellite images. At first stage, a watershed segmentation technique is developed to classify the image into various regions. Then, a knowledge is built for road and used to extract the road regions.

In this study, we use panchromatic and multi-spectral images of the IKONOS satellite as test dataset. The experiment result shows that the proposed technique can generate suitable and meaningful road objects from high spatial resolution satellite images. Apparently, misclassified regions such as parking lots are recognized as road needed further refinement in future research.
Key Words: Road Extraction, High Resolution Satellite Images, Image Segmentation, Watershed.

1. Introduction

Due to the progress of satellite imaging system recently, the image resolution of commercial satellite can reach to about 1 meter in panchromatic mode. Such high spatial resolution images certainly will provide lots of detail for remote sensing users. Nevertheless, the complex image content will make it difficult to develop image algorithms for automated image feature extraction and pattern recognition. The segmentation method is a widely used technique for extracting region features from images. Especially for satellite images, segmentation is usually regarded as a preprocessing for image classification [1].

In this study, we suggest an image segmentation method based on watershed [2][3] technique to extract road features from high resolution images. The basic concept of image segmentation by watershed is to perform watershed operation on an edge map that is obtained from the source images. Because of the complex texture of high spatial resolution images, watershed algorithm usually causes over segmentation. To avoid such consequence, a smoothing filter must be used in a priori [4]. There are some smoothing algorithms to perform noise reduction and preserve edge information [5][6]. In this study, the watershed algorithm is used as the first stage procedure, and a second stage procedure is introduced to extract road features.

2. Methodology

The proposed scheme can be divided into two stages: training stage and analysis stage. The objective of training stage is to create a knowledge base for road objects from a high resolution image. Then, the analysis stage is followed to apply the knowledge base to classify road areas for other part of high resolution images.

1) Training Stage

Firstly, a Gaussian operator is used as a smooth mechanism to reduce the local variance of input image. Secondly, the square sum of the images produced by Sobel operators in column and row directions is used to measure intensity of edge for smoothed image. Thirdly, based on the watershed technique of morphological theory, the concave regions in the edge image can be detected and result an initial segmentation. Fourthly, the small segments are eliminated by merging the neighboring patches based on the threshold of gray level difference and obtain a refined segmentation result. Then, we take multi-spectral and panchromatic information for each segment as its attributes by averaging the corresponding area of multi-spectral and panchromatic image. In addition, the texture and shape information is also calculated as extra attributes for each segment. Here the texture and shape information we used are the standard deviation from panchromatic image and the compactness for each segment. The compactness is defined as follows:

$$\text{Compactness} = \frac{\text{Shape Area}}{\text{Circular Area That Enclose the Bounding Box of the Shape}}$$

At last, an ISODATA unsupervised classifier and a series of regrouping procedure are employed to generate the road objects for input image. Then, the attributes of these objects are used to create the knowledge base for next stage. Figure 1 is the flowchart for this stage.

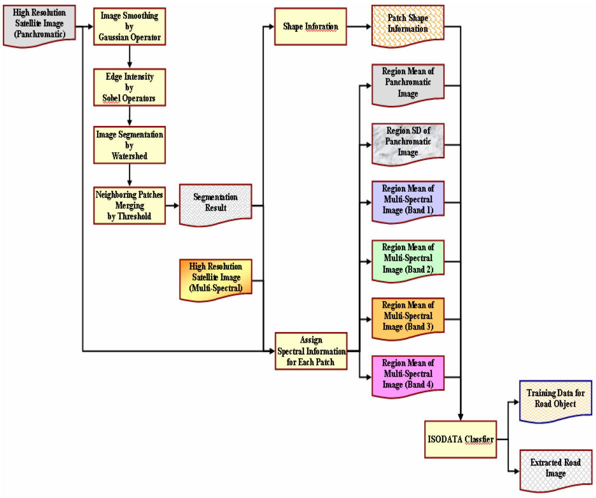


Fig. 1. Flowchart for training stage.

2) Analysis Stage

At first, like the previous stage, the preprocessing procedure to generate segment attributes for the images has to perform as well. Then, based on a maximum likelihood classifier, we apply the knowledge base built in previous stage as training samples to classify the road features for the other input images. Figure 2 is the flowchart for this stage.

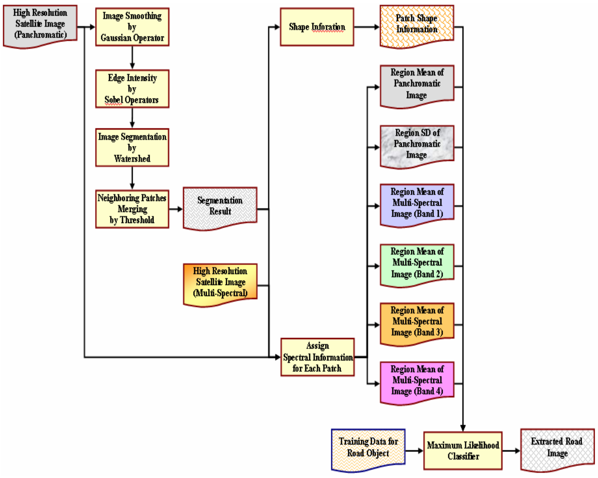


Fig. 2. Flowchart for analysis stage.

3. Experimental Result

Figure 3 Shows the input images for training stage. This dataset is IKONOS satellite images acquire on Oct. 9, 2000. The spatial resolution is 1 meter for panchromatic image and 4 meters for multi-spectral image. The ground coverage of this dataset is 1.5KM by 1.2KM. Figure 4 illustrates the road objects extracted by the proposed scheme. These objects are used to create knowledge base for analysis stage.

Panchromatic Image

Multi-Spectral Image

Fig. 3. IKONOS satellite images used in training stage.

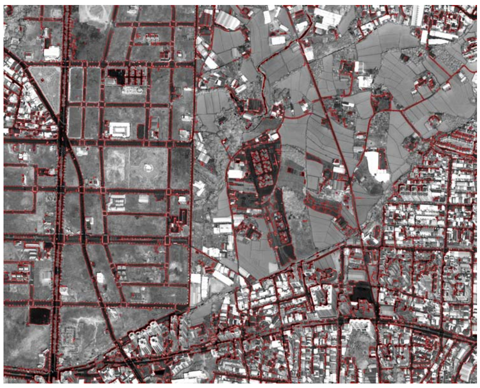
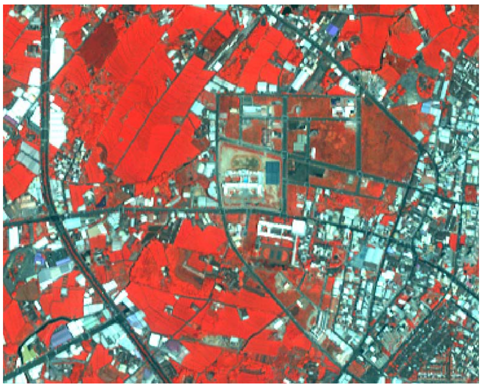


Fig. 4. The road objects extracted in training stage.

Figure 5 Shows the input images for analysis stage. This dataset is also IKONOS satellite images acquire on Oct. 9, 2000. The ground coverage of this dataset is 1.5KM by 1.2KM. Figure 6 illustrates the road area extracted by the proposed scheme. Obviously, most road objects are extracted for high spatial resolution satellite images.

Panchromatic Image



Multi-Spectral Image

Fig. 5. IKONOS satellite images used in analysis stage.

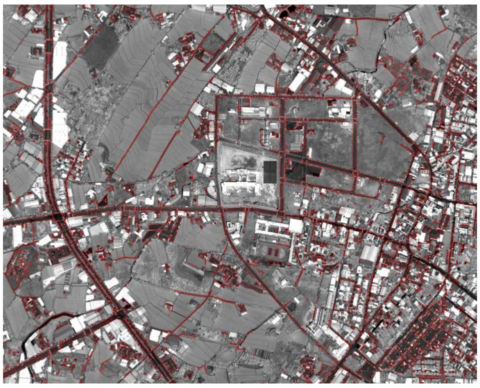


Fig. 6. The road objects extracted in analysis stage.

4. Conclusion

In this study, we use panchromatic and multi-spectral images of the IKONOS satellite as test dataset. The experimental result shows that the most of road area is successfully detected. Some misclassification like parking lots and shadow area is recognized as road. The further refinement will be included in future research.

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