Urban Trunk Roads Extraction Using Hough Transform and NDVI in Airborne Hyperspectral Remote Sensing Images

Cailing Wang¹, Pu Guo¹, Hongwei Wang², Fan Yang¹

¹Xi’an Shiyou University, Xi’an 710065, China
²Engineering University of CAPF, Xi’an 710086, China
azering@163.com

Abstract. In order to extract urban main road in hyperspectral remote sensing images, this paper first employs Hough transform in three main different bands of hyperspectral image datasets to identify and extract urban main road. Then, Normalized Difference Vegetation Index (NDVI) is calculated to extract vegetation information and eliminate the disturbance brought by vegetation such as trees along roads and others vegetation landscape. The experiments use two real airborne hyperspectral datasets and results show that method proposed can effectively extract the main road in airborne hyperspectral remote sensing images by Hough transform and NDVI.

1. Introduction

With the development of hyperspectral remote sensing technology, the urban target classification and detection has been a research hot pot. Using hyperspectral images to extract urban roads is of great significance to urban planning and traffic development. Many methods and algorithms for extracting road information from remote sensing image have been proposed in literature [1], which involve pattern recognition, mathematical model, computer vision and other aspects.

For example, Wang Runsheng and others put forward a method to automatically extract the straight trunk road network from urban aerial images. The method proposed takes the road characteristic line for layered symbol firstly. Secondly, the whole image is divided into several sub blocks, and then detects road in each sub-block based on line extraction roads [2]. Luo Qingzhou and others put forward the way of the combination between the spectrum and shape feature extraction method. The method uses shape features to remove disturbance terms, making the road centerline and planar road can be obtained [3]. Tang wei and others proposed an object-oriented technology to achieve the hyperspectral remote sensing image road information extraction. The method can make full use of road shape and texture information, overcome the spectral characteristics of the noise phenomenon, so that the road extraction accuracy increased[4]. Shen zhaoqing and others proposed a fast extraction algorithm for road features of hyperspectral remote sensing images based on support vector machines, which can identify different road features and improve the execution efficiency. However, the proposed algorithms shown above cost a large amount of computation and much time consuming[5].

An adaptive road extraction method proposed by Yangchunhua et al uses road vector lines to expand the area without manual intervention and adjustment of parameters, which makes the road extraction more accurate, but the algorithm is more complex. Efficiency still needs to be improved [6].

Considering the airborne hyperspectral remote sensing image spectral characteristics of the urban road have obvious spectral characteristics and geometric characteristics [7]. In this paper, we first use
hyperspectral remote sensing image gray scale to remove noise, and then use the classical Canny algorithm for edge detection and NDVI for hyperspectral images for removing vegetation surrounding road. Finally, we use Hough transform to detect line according to the linear characteristics, extract the complete urban main road. Our experimental results, conducted with two real hyperspectral scene collected by an adaptive multi-modal (panchromatic and hyperspectral) sensor equipped on onboard platform, indicated that the proposed method can extract the main road accurately.

2. Proposed Approach

2.1. Geometric feature of roads
The urban trunk road has obvious linear characteristics, and the length is much longer than the width. The urban trunk road is straight and long, and the two sides of the road are parallel straight lines. The urban road and the surrounding buildings have obvious boundaries, and the road surface gray level has little change.

2.2. Spectral characteristics of roads and vegetation
The spectral characteristics of urban roads are very similar to the buildings. However, due to complex road materials, aging road surface and excessive noise interference on both sides of the road, the spectral characteristics of urban roads may be complicated. Vegetation around the trunk road also has obvious spectral characteristics. Vegetation will show different reflectance in different spectral bands and form different vegetation index. The normalized difference vegetation index is an indicator used to analyze remote sensing images to determine whether the observed target area is covered by green plants and the degree of vegetation coverage. Therefore, the normalized difference vegetation index can be calculated in order to extract the vegetation information in the image.

2.3. Spectral band selection
Considering that the hyperspectral image has a number of bands, multiple bands of the same image can be selected for experiments to make the road extraction results more accurate. To consider time consumption, we need to reduce the spectrum bands dimension or select few bands for calculation. In this paper, we chose only one band for urban trunk road extraction.

2.4. Hough transform
The main principle of Hough transform is to map the points on the original image to the parameter space for accumulation through the duality of points and lines, so as to transform the detection problem of the given curve in the original image into the problem of finding the peak value in the parameter space. A point on a straight line in a Euclidean space is a sine curve in the Hough parameter space. Multiple points on the same line in Euclidean space are a sine curve cluster in Hough parameter space and the curve cluster intersects at a point, which is called the peak point.

When Hough transform detects a line, line L in Euclidean space is \( y = kx + b \), the three data points on L are expressed as \((x, y)\), line L is expressed as \((\rho, \theta)\) in Hough parameter space, point P is the peak point in Hough parameter space, and its meaning is the L line in Euclidean space. That is, the line in the x-y plane \( y = kx + b \) is transformed into \( x \cos \theta + y \sin \theta = \rho \) in a parameter space, as shown in Fig.1:
In this way, all points of the common line in the image space correspond to all lines that intersect at the same point in the parameter space, and the length of the line in the image space is transformed into the number of lines passing through the point in the parameter space.

2.5. Urban trunk road extraction by Hough transform and NDVI

In this paper, we proposed a new spectral-spatial method for extract urban trunk road in airborne hyperspectral remote sensing images. The proposed method consists of line extraction by Canny and Hough transform in spatial domain and vegetation disturbance removing by NDVI in spectrum domain. The procedure is as shown in Table 1.

| Table 1. The procedure of proposed method |
|------------------------------------------|
| **Input:** the hyperspectral image dataset |
| **Output:** road map                     |
| 1 Selected specific band                 |
| 2 Binary image by Canny                  |
| 3 Line extraction by Hough transform     |
| 4 Calculating NDVI and binary result      |
| 5 Line connection based on NDVI result    |
| 6 Return road map                        |

3. Experimental results

The experimental data used in this paper is published by the Rochester Institute of Technology Multi-object spectrometer (RITMOS). The spatial resolution is 0.3 m. The spectral range is 400nm to 1000nm, and the band number is 61. The two images are shown in Fig.2 and Fig.3.
Form the Fig.2 and Fig.3, we can see that the images are quite different in each spectrum band, that is why we can choose one specific band for road extraction. Since there is a large amount of vegetation on both sides of the road in the hyperspectral remote sensing image. It can be seen that the road is relatively accurate in the band of 940nm, so band 940nm image is selected to extract trunk road with Hough transform.

Since there is a large amount of vegetation on both sides of the road in the hyperspectral remote sensing image, we use the normalized difference vegetation index in the image and extract the vegetation to make the road connected. The two datasets experiment result are shown Fig.4 and Fig.5.
4. Conclusion
In this paper, the urban trunk road extraction method of airborne hyperspectral remote sensing image is proposed. The trunk road in the image is detected and extracted successively through band selection, edge detection technology and Hough transform. Then the vegetation information in the road is extracted by calculating NDVI to make the road connecting. The experiments done in two real hyperspectral remote sensing images indicate that hyperspectral remote sensing images can supply more information for urban trunk road extraction, and get more accurate results. Specifically, there are two main advantages. The one is that different band image can get different information of spatial features, the other is that hyperspectral make it easy for us to find the best example.

However, in hyperspectral remote sensing images, there are not only straight trunk roads, but also many curved roads and short branch roads. The straight lines detected by Hough transform may be incomplete or deviated. In the future, road extraction from hyperspectral remote sensing images should be further improved.

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