Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 3, No. 3, 2022

Study on Shadow Extraction of Urban Buildings Based on ZY-3

Dan Wu[1, 2, 3, 4], Liangyan Yang[1, 2, 3, 4]

[1]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[2]Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[3]Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of natural Resources, Xi'an 710075, China
[4]Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an, 710075, China

Abstract: Shadow is one of the universal features of high resolution remote sensing images. As an important symbol of image interpretation, shadow can reflect the height of ground objects and other information. But at the same time, the existence of shadow will affect the image interpretation, information recognition and extraction. Therefore, it is very necessary to study and extract shadow information in remote sensing image. In this paper, the image features of each band of the Yuan-Yuan-3 satellite were analyzed, and the shadow was extracted by the integrated method based on principal component transform and HIS transform. The research results show that the creation of shadow index on the basis of the two transformations can effectively enhance the spectral features of the shadow and effectively extract the shadow.

1. Introduction

Shadow is a common image feature in high-resolution remote sensing images. It is caused by the fact that buildings, trees and other ground objects block the sun rays, which weakens the reflected light intensity and reduces the received signal of optical sensor in the blocked area, and forms darker gray scale images in the image area at the corresponding position [1-3]. The existence of shadow weakens the spectral information in the image and affects image processing operations such as image information extraction, change detection and image segmentation [4]. At the same time, the existence of shadow leads to the loss of the ground object information covered by the shadow area, which brings difficulties to the target recognition. Therefore, it is of great significance to study the shadow extraction of buildings. Therefore, in recent years, many scholars have realized the importance of high resolution image shadow detection and necessary information compensation and have done a lot of research on it. How to accurately detect the shadow region of remote sensing image and compensate the necessary information has become a hot issue in the field of remote sensing.

The existence of shadow causes partial loss of ground object information contained in the shadow area, which brings difficulties to target recognition. Therefore, the study on the extraction of building shadow is of great significance [5]. However, there are still several problems in extracting building shadows from remote sensing images:

The shadow detection method of one kind of image cannot be applied to another kind of remote sensing image due to the difference of remote sensing image acquisition sensor;

(2) The shape and structure of urban buildings are ever-changing, and their distribution, size and orientation are difficult to determine;

(3) The spectral characteristics of water and bluish features in the image are similar to those of the shadow, which cannot be completely distinguished.

Through the extraction of building shadows from remote sensing images, the main methods include single-band threshold method and multi-spectrum analysis spatial modeling method for shadow extraction [6]. However, the band threshold method is relatively simple. Firstly, the spectral characteristics of ZY-3 multi-spectral remote sensing image and typical ground objects are analyzed to find out the band suitable for shadow extraction. However, this method cannot effectively distinguish water and shadow, and the shadow extraction effect is not obvious. Multispectral analysis is to analyze the spectral values of ground objects based on their different ability to reflect light, and extract shadows from images through algebraic and logical operations. In this paper, by analyzing the spectral characteristics of Resource-3 multi-spectral remote sensing image, the difference of spectral values of ground objects in each band and the relationship between each band are used to find out the band suitable for shadow extraction. By using algebraic operation, a high-precision shadow extraction model is built to effectively extract the shadow of urban buildings.

2. Data Sources and Research Methods

2.1. Data Overview

As China's first independent civilian high-resolution stereo mapping satellite, ZY-3 has an orbital altitude of 506km and an orbital period of 38 minutes. It can obtain long-term, continuous and accurate stereo panchromatic images, multispectral images and their data [7]. The Ziyuan-3 satellite is loaded with four cameras, one of which is a panchromatic camera, and two of which are arranged in front, front and back modes for stereoscopic imaging. It can realize panchromatic front, rear, panchromatic front and multispectral front. The panchromatic band wavelength of the satellite is 450μm to 800μm, the multi-spectral wavelength is 450μm to 520μm in blue band, 520μm to 590μm in green band, 620μm to 690μm in red band, 770μm to 890μm in near-infrared band, and the minimum scanning width is 52 km. The re-visit period is five days.

2.2. Spectral characteristics of ground objects

(1) Spectral characteristics of shadows: the gray value of ground objects is not only affected by the ground objects

themselves on the absorption and reflection of light, but also affected by the shooting time and weather conditions. Therefore, when the shadow area is affected by these factors and coincides with some ground objects with low brightness radiation, the shadow will be confused with some ground objects (such as water bodies and vegetation, etc.), and their gray values are particularly similar, so it is difficult to extract the shadow. In the shaded region, there is little correlation between the spectral values of the blue band and the green band. In general, the ground objects in the non-shaded area will not only be irradiated by direct solar light, but also be irradiated by ambient reflected light and scattered light, while the ground objects in the shaded area have no direct solar light. The formation of shadow is mainly concentrated in the visible and infrared bands, and the intensity of scattered light decreases with the increase of wavelength. Therefore, the spectral value of the shadow region in the green band decreases sharply compared with that in the blue band, and there is little correlation between the two.

The shadow region is characterized by low frequency in the frequency domain [8]. Digital image through the Fourier transform, will be converted from the spatial domain to the frequency domain, then the shadow region in the low frequency part, this is because the brightness of the shadow region is only composed of the radiation of the region, and the reflected light is blocked, so the brightness of the shadow region is compressed, the gradient change value of the shadow region is correspondingly smaller, in the frequency domain is the low frequency part.

(2) Spectral characteristics of water body: the spectral characteristics of water body are mainly determined by the material composition of water itself, and are also affected by various water states. When the sun shines on the water surface, only a small part of the light is reflected back into the air by the water surface, and most of the light is incident on the water body. The light incident on the water body is mostly absorbed by the water body, part of it is reflected by the suspended matter in the water (sediment, organic matter, etc.), and a small part of it is transmitted to the bottom, which is absorbed and reflected by the bottom. Some of the radiation reflected by the suspended solids and the bottom returns to the surface and back into the air. Therefore, the radiation received by the remote sensor includes the reflected light from the water surface, the reflected light from suspended matter, the reflected light from the bottom and the scattered light from the sky. Due to the different water surface properties, the properties and content of suspended substances in the water, and the water depth and bottom characteristics, the reflected spectral characteristics received by the sensor are different, which provides the basis for remote sensing water detection.

(3) Spectral characteristics of vegetation: Plants on the surface of the earth have obvious spectral reflection characteristics, which are different from the surface features of water, soil and other typical areas. Their ability to absorb or radiate electromagnetic waves to the sun or artificial objects is mainly determined by the chemical characteristics and morphological characteristics (natural growth or physical factors of plants) of the vegetation. This very special sign is closely related to the development of vegetation, the health of vegetation and the growth conditions of vegetation. The spectral characteristics of plants can effectively distinguish them from other features in remote sensing images. The pigment absorption capacity of vegetation determines the spectral reflectance of visible band, the cell structure determines the spectral reflectance of near infrared band, and the water vapor absorption determines the spectral reflectance of short wavelength infrared. At the same time, different plants have their own spectral characteristics, which can be used to distinguish vegetation types, growth and biomass estimation.

2.3. Image Features

The resource satellite ZY-3 is the first generation of high resolution resource satellite developed by our country. In terms of texture features, the image can better reflect the spatial features and structural differences of ground objects. Compared with the texture of SPOT-5, the ZY-3 satellite is more abundant.

For the extraction of water bodies, buildings and other information, the ZY-3 satellite has lower band correlation, but for the extraction of vegetation information, the near-infrared band data can achieve better results. Generally speaking, the image data of the ZY-3 satellite has obviously better performance in terms of image quality, texture features and other aspects, and can basically meet the requirements of medium and small scale mapping and application. After the fusion with the three-line array high-resolution panchromatic image of the ZY-3 satellite, it can meet the specific requirements in a specific range.

Table 1. Statistical results of spectral brightness values of sample points

		Water	Shadow	Vegetation	Other
B1	Minimum value	276	258	242	279
	Maximum value	312	357	312	866
	Mean value	296	292	277	405
	Variance	6	14	11	56
B2	Minimum value	283	259	235	315
	Maximum value	327	383	326	1040
	Mean value	309	293	275	482
	Variance	8	18	13	77
B3	Minimum value	179	172	152	224
	Maximum value	204	288	241	904
	Mean value	188	205	187	422
	Variance	3	16	13	77
B4	Minimum value	159	190	218	385
	Maximum value	242	389	551	1409
	Mean value	180	246	413	607
	Variance	9	24	76	98

Through the statistical analysis of the shadow of ZY-3 multi-spectral remote sensing image and the spectral values of typical ground objects, the spectral characteristics of different ground objects are as follows: the first and second band values of water are close, while the third and fourth band values are relatively small, and the range of regional values is also relatively small. The first and second band values of the shadow are also close, the third band values are small, but the fourth band value range is larger and the maximum value is larger. The first and second band values of greenbelt are close, the third band values are small, and the fourth band values are larger, and the maximum value is larger than that of water and shadow. For other factors, the difference between the values of the four bands is relatively large, especially the difference between the values of the second and fourth bands and the band range is larger.

From another Angle, the bands of different objects with the same wavelength are compared, and the conclusion is drawn: In the first, second and third bands, the spectral values of shadow, water body and vegetation are all close, so in the first three bands, the confusion of the three is relatively large. In the fourth band, the shadow is difficult to distinguish from the water body, and their spectral values are relatively similar, while the spectral values between them and other ground objects are quite different. Therefore, the fourth band can be selected to complete the rough extraction of shadow.

2.4. 1.4 Research Methods

Principal component transform [9] (K-L transform) is a linear combination of a group of multi-spectral images using the K-L transform matrix to transform each band with strong correlation to a few completely independent bands. In this experiment, the principal component transform is firstly carried out on the multi-spectral remote sensing image of the ZiyuZ-3 satellite, and the transformed image is analyzed. The first principal component (PC1) after transformation contains most of the information of the image, so the first principal component highlights the main information of the image to achieve the purpose of enhancing the image. After a lot of experiments, it is found that when the proportion of dark material on the image is large, the gray value of the shadow region reflected in the first principal component is positive, and the lower the brightness value is, the greater the value of the first principal component is. When the proportion of dark material in the image is small, the shadow area reflected in the first principal component is negative, and the lower the brightness value is, the smaller the value of the first principal component is. The method to judge whether the shadow area is positive or negative in the first principal component image is sampling and analysis.

HIS color model [10] well reflects the way human visual system perceives color, perceives color with three basic characteristic quantities: hue (H), saturation (S) and intensity (I). In HIS model, the shadow area has a certain uniqueness compared with other areas because the sunlight is blocked by objects, so the brightness value of the shadow area is relatively low, that is, the value of I in the shadow area is small, and the color of the shadow area is close to the dark color of black with a large hue value, so the value of H in the shadow area is relatively large.

Firstly, principal component transformation is carried out on the original image. Since the first principal component contains a large amount of information and the contrast of each feature in the first principal component is relatively large, the first principal component is standardized, and the processing method is shown in formula 1 and Formula 2:

$$\text{PC1 minus} = (\text{b1 gt } 0)\times 0+(\text{b1 lt } 0)\times \text{b1} \tag{1}$$

$$\text{PC1nor}=\text{PC1 negative} / \min(\text{PC1}) \tag{2}$$

In the formula, b1 represents the first principal component, min(PC1) represents the minimum value of the first principal component, and PC1nor represents the normalized value of the first principal component, that is, the standardized value.

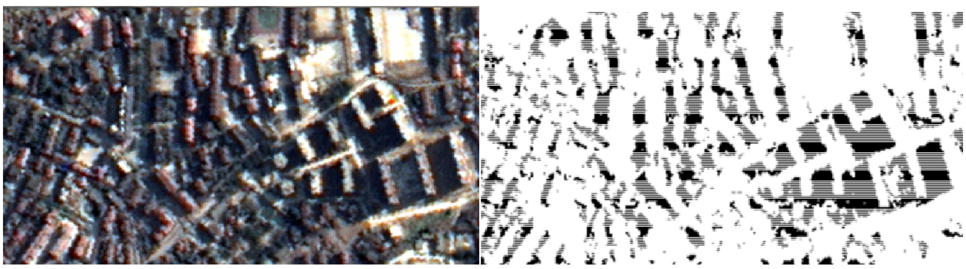
Due to the values of I component and S component of HIS model, only the values of shadow and water body in PC1nor are greater than I value, so the difference method can distinguish shadow and water body from other ground features, and the difference between shadow PC1nor and I is greater than that between water body PC1nor and I. Compared with S and I, the gap between water body and shadow PC1nor and I is larger. Therefore, according to the above principles, a new shadow index SI can be constructed, and the expression (3)

$$\text{SI}= (\text{PC1nor} - \text{I})\times(1+\text{S}) / (\text{PC1nor}+\text{I}+\text{S}) \tag{3}$$

Where SI is the shadow index, I and S respectively represent the I component and S component in HIS model, and PC1nor represents the normalized value of the first principal component.

3. Experimental Results

In order to verify the accuracy and applicability of the model presented in this paper, the image of Ziyuan-3 satellite was obtained for experimental analysis. The synthetic true color image is shown in Figure 1 (a).



(a) True color image (b) shadow extraction results

Figure 1. Experimental results

The experiment shows that the method of constructing shadow index through principal component transformation and HIS transformation can effectively enhance the spectral value of shadow in the image and effectively extract the shadow of urban buildings. For the extracted results, some processing, such as morphology operation and filtering processing, is needed. In this experiment, corrosion operation is used to eliminate some interference factors. Corrosion operation is a kind of operation in morphology operation. It is a process used to eliminate boundary points and make the boundary shrink inward. Corrosion operation can be used to eliminate small and meaningless objects in the process of image extraction.

4. Conclusion

By studying the existing shadow extraction algorithm and combining the spectral characteristics of various objects in ZY-3 multi-spectral remote sensing image, this paper uses PCA transform and HIS transform to construct the shadow index method to extract the shadow area of urban buildings. Through the experimental research and analysis, satisfactory results have been achieved. Experiments show that the method of constructing shadow index through principal component transformation and HIS transformation can effectively enhance the spectral value of shadow in the image and effectively extract the shadow of urban buildings. However, in the final extraction of shadow, it is necessary to determine the threshold value, which will bring some errors. Therefore, this method needs further research and improvement for building shadow.

To sum up, there are still many problems in the process of shadow extraction, which need to be further studied and improved, especially at present, there are few kinds of studies based on the ZY-3 satellite, and many methods are not universal, so greater efforts should be made in this regard.

Acknowledgment

This paper was supported by Shanxi Province Land Enginaeering Construction Group Project DJNY2022-28.

References

[1] Hu Xingshu, Gong Jianya, Pan Jianping. Current situation and development trend of contemporary Remote sensing technology [A]. Journal of Wuhan University (Engineering Science),2003,36 (3) : 195-198.

[2] Wang Shugen,Guo Zejin,Li Deren .Shadow Detection and Compensation for Color Aerial Images [A].Geo-spatial Information Science (Quarterly), 2003, 6 (3) : 20 to 24.

[3] Xu Qiuhong, Ye Qin. A Shadow elimination method for urban high-resolution Remote Sensing Images based on color constancy theory [A]. Remote Sensing Information Theory Research,2010,77 (11) : 13-16.

[4] Xu Honggen, Song Yan. Change detection method of high resolution Remote Sensing image considering shadow information [J]. Land and Resources, 2013,25 (4):16-21.

[5] Wei Lifei, Zhong Yanfei, Zhang Liangpei, Li Pingxiang. Remote Sensing image change detection based on Multi-band information fusion [J]. Journal of Wuhan University. Information Science Edition, 2014,39 (01) : 8-11.

[6] Bao Haiying, Li Yan, Yin Yongyi. Study on shadow detection and shadow elimination of urban aerial image [A]. Remote Sensing Applications, 77 (10) : 44-46.

[7] Wang Chang, Gu Fa, Yu Tao, Xie Yong, Xie Yanhua, Li Xiaoying. On-orbit MTF measurement and image Restoration of Ziyuz-3 Satellite [A]. Computer Engineering,2013,39:1-5.

[8] Shadow detection of high-resolution satellite remote sensing image based on gradient feature [A]. Journal of Fuzhou University (Natural Science Edition), 2008,36(5):677-682.

[9] J.Cihlar,J. Howarth .Detection and Removal of Cloud Contamination from AVHRR Images.IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 1994, 32(3):583-589.

[10] Shan Lu,Wei Huang,Riu Huang.Shadow Detection of Color Urban Aerial Images[J].School of Communication And Information Engineering,2010:1610-1613.