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Shadow Detection Using Object Oriented Segmentation, Its Analysis And Removal From High Resolution Remote Sensing Images

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Abstract

Very high resolution satellite images available from satellites such as QuickBird, IKONOS etc are usually affected with shadows. These shadows reduces the information content of the images. In this paper, an object oriented shadow detection method is used to detect the shadows. In this method each object in the input image is extracted through a segmentation process. Suspected shadows are detected by comparing the threshold obtained from the original image and the gray scale average of each object in the segmented image. Dark objects which may be included in the suspected shadows are eliminated by com-paring the gray scale average in different image bands. For the restoration of information, relative radiometric correction is used. For this inner-outer outline lines along the shadow boundary are generated. For shadow removal, relative radiometric correction is applied to the homogeneous points obtained from IOOPL similarity matching. Experimental result shows that the proposed algorithm effectively detected majority of shadows within the high resolution satellite images compared to pixel based methods.

Index Terms— Inner-Outer Outline Profile Line (IOOPL), object oriented, relative radiometric correction, shadow detection, shadow removal.

I. INTRODUCTION

Satellite remote sensing is the acquisition of information about the surface of earth using satellites. Due to the progress in remote sensing a variety of satellites are used for the observation of earth surface. One of the basic features of high resolution remote sensing images is shadows. Although presence of shadows is used for the construction of 3D scene information they cause total or partial radiometric loss in the affected areas. So there is a need to detect and remove the shadows present in images.

Processing of shadows involves two procedures. Shadow detection and shadow compensation. Mainly there are two approaches for shadow detection. They are model based approaches and shadow feature based approaches. Model based methods use prior information such as scene, moving targets and camera altitude to construct shadow models [2]. Shadow feature based methods identifies shadow areas as gray scale, brightness, saturation and texture [3]. A shadow region appear as a low grayscale value in the image. Shadows can also be detected by converting RGB images into invariant color spaces, HSV, HCV, YIQ, C_1 C_2 C_3 etc [4], [5]. Shadows can be also detected using an adaptive blackbody radiator model [6]. Multisource data fusion, masking, radiometric enhancement etc are some of the methods used for shadow compensation [3]. Three different algorithms are used in order to radiometrically restore the detected shadow areas. These algorithms are gamma correction method, linear correlation method and histogram matching method. Most of the techniques for shadow detection aims at obtaining shadows at pixel level of the image. An object oriented shadow detection could effectively detect shadows. Object based approach do not operate directly on individual pixels but on image objects.

II. METHODOLOGY

Shadows are created because the light source has been blocked by something. There are two types of shadows: the self-shadow and the cast shadow.

In this paper, we mainly focus on the shadows in the cast shadow area of the remote sensing images. The block diagram for object oriented shadow detection and removal is shown in Fig.1. Segmentation is used to create image objects. Each image object is extracted through segmentation. Each object is compared with the histogram of the original image to check whether it is shadow affected or not. Shadow detection method will be completed only if the false shadows are eliminated from the detected shadows. For shadow removing before applying radiometric correction inner and outer lines of the shadow boundary are extracted. Then relative radiometric correction is applied to points extracted from the inner and outer profile lines. The basic block diagram for the detection and removal of shadows in high resolution remote sensing images are as shown in the Figure 1.

A. Object Oriented Segmentation

Segmentation is the underlying concept for creating objects from pixels. The segmentation process is dividing the image into regions or objects that have common properties. Typical image segmentation techniques involve one of the two processes. Region merging according to some measure of homogeneity and separation of objects by finding edges using gradients of digital numbers (DNs) between neighboring pixels. The segmentation method used for object oriented shadow detection is called the active contour model segmentation. The active contour/snake model is one of the most successful variational models in image segmentation. Active contour model segmentation starts with an initial boundary shape represented in the form of spline curves and iteratively modifies the boundary by applying various internal energy constraints such as shrink or expansion operations. It consists of evolving a contour in images towards the boundaries of objects. The snake model is highly sensitive to the initial conditions. Each objects in the input images are extracted using active contour model segmentation.

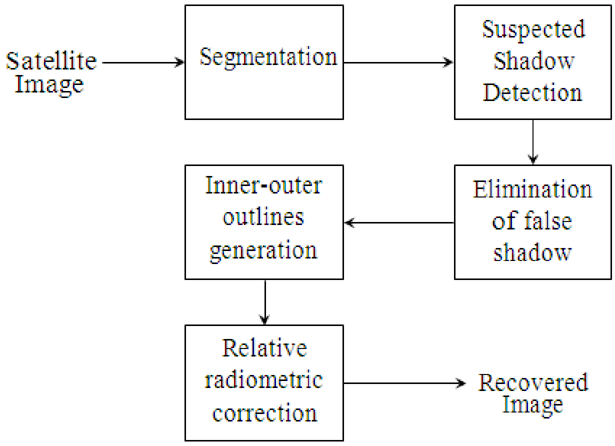

Fig. 1. Block diagram of shadow detection and removal

B. Suspected Shadow Detection

After segmentation an input image where each object in the image is separated is obtained. Since it is object oriented shadow detection each object is compared with the histogram of the original image to check whether it is shadow affected or not. For shadow detection a threshold is calculated from the histogram of the input image. This threshold is compared with the gray scale average of each object obtained in segmentation process for shadow detection. Otsu thresholding method is used to find the threshold from the input image.

Due to Rayleigh scattering, threshold is calculated using Otsu thresholding method only at red and green wavebands. Grayscale average of each object is compared with the thresholds in both red and green wavebands for shadow detection. An object is determined as suspected shadow if its gray scale average is less than the thresholds in both red and green wavebands.

C. Elimination Of False Shadow

High resolution satellite images contains different objects such as buildings, trees, water bodies etc. These dark objects which are actually not shadows may miss classify as shadows and may include in the detected shadows. So for accurate detection of the shadows these dark objects should be eliminated. There is smaller gray scale difference between a shadow area and a non-shadow area in the blue (B) waveband than in the red (R) and green (G) wavebands due to Rayleigh scattering. So for the majority of shadows, the gray scale average at the blue waveband G_b is slightly larger than the gray scale average at the green waveband G_g. So a comparison between the grayscale average at the blue waveband G_b and the gray scale average at the green waveband G_g eliminate suspected shadows.

D. Inner-Outer Outlines Generation

Shadow areas in an image, are recovered using a shadow removal method based on inner-outer outline profile lines (IOOPL). Diagram of the inner and outer outlines generation is shown in the Fig.2.

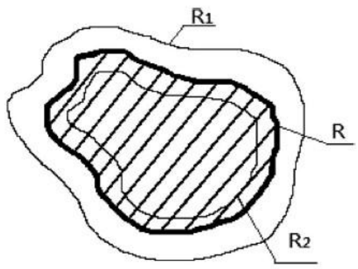

Fig. 2. Shadow boundary, inner and outer outline lines

As shown in Fig.2, R is the vector line of the shadow boundary obtained from shadow detection, R_2 is the outer outline in the non-shadow area obtained after expanding R outward, and R_1 is the inner outline in the shadow area obtained after contracting R inward. There is a one-to-one correspondence between nodes on R_1 and R_2. When the correlation between R_1 and R_2 is close enough, there is a large probability that this location belongs to the same type of object. The gray scale value of the corresponding nodes along R_1 and R_2 at each waveband is collected to obtain the inner-outer outline profile lines (IOOPL). The outer profile lines (OPLs) in the shadow area are marked as inner OPLs and the outer profile lines in the non-shadow area are marked as outer OPLs. Homogeneous sections on inner and outer outline profile lines are obtained by IOOPL matching. IOOPL matching is the process of obtaining homogeneous sections by conducting similarity matching to the IOOPL section by section.

If the correlation coefficient is large, then this line pair belongs to the same type of object and they are homogeneous sections and are considered to be matching. If the correlation coefficient is small then the sections are non homogeneous and are ruled out. Only the homogeneous sections obtained from IOOPL matching is used for radiometric correction.

E. Relative radiometric correction

Relative radiometric correction is used for restoration of information. Relative radiometric correction calculates the radiation parameter according to the homogeneous points of each object and then applies the relative radiation correction to each object.

Relative radiation correction assumes that a linear relation-ship exists between the grayscale value digital number (DN) of the shadow and DN of the non shadow. All shadow points are corrected according to the equation

$$DN_{non\ shadow} = a_k \times DN_{shadow} + b_k \quad (1)$$

where, $DN_{non\ shadow}$ is the pixel gray scale of the shadow after correction, DN_{shadow} is the pixel grayscale of the shadow before correction. The coefficient a_k represent the ratio of the standard deviation of outer homogeneous section and inner homogeneous section at the corresponding waveband. The coefficient b_k represents the mean.

III. EXPERIMENTAL RESULTS AND DISCUSSION Simulation is performed using the MATLAB version
R2014b. The simulation is performed on images acquired using QuickBird satellite. The input images used for shadow detection and removal are shown in Fig.3. For object oriented segmentation active contour model segmentation is used. The output of segmentation is given in Fig.4. Active contour model segmentation effectively segment shadows and dark objects such as vegetation and water bodies into different subjects.

Fig. 3. Input image

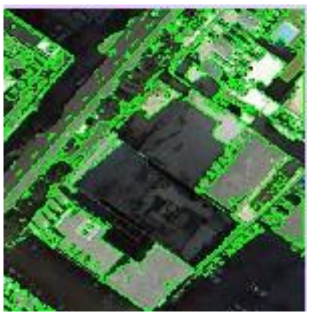

Fig. 4. Segmented image

The shadow detected image is shown in Fig.5. Suspected shadows may contain false shadows. The image for elimination of false shadows is shown in Fig.6.

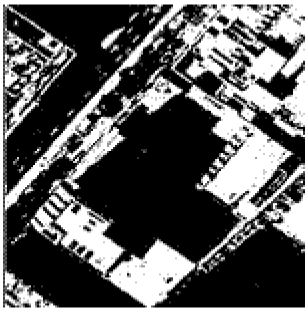

Fig. 5. Suspected shadow detected image

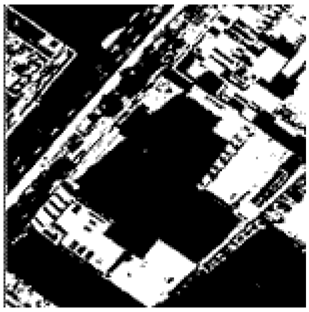

Fig. 6. False shadow eliminated image

The inner outer outlines generation is shown generation is shown in Fig.7. The green lines shown in the figure indicates the shadow boundary. The inner outline obtained by contracting the shadow boundary is indicated by blue line and the outer outline obtained by expanding the shadow boundary is indicated by red line. Relative radiometric correction could produce better results if both the input and output points belongs to the same category of objects. By applying IOOPL matching to each shadow, homogeneous sections that represent objects of the same category in different lighting conditions are obtained. Final output shadow removed image is shown in Fig.8.

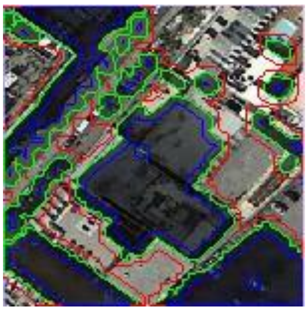

Fig. 7. IOOPL generated image

Fig. 8. Shadow removed image

IV. CONCLUSION

An object oriented method for detection and removal of shadows from high resolution remote sensing images is employed. Active contour model segmentation is used to segment image objects. Then suspected shadows are selected through spectral features. False shadows are eliminated from the detected shadows. Comparison of the grayscale average of false shadows in the blue and green wavebands are used for false shadow detection. IOOPL is the base for the application of radiometric correction for shadow removal. Relative radiometric correction is applied to the homogeneous sections obtained after IOOPL matching. Compared to existing pixel based methods object oriented method of shadow detection stably and accurately detected shadows.

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