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A Novel Shadow Detection and Shadow Removal Algorithm for Optical Satellite Images

Anusuya.P[1] and Dr.K.Venkateswaran[2]

[1]*PG Scholar, Communication Systems, Kongu Engineering College, Tamilnadu, India. Email: ananu226@gmail.com*
[2]*Assistant Professor (Sr.G), Department of ECE, Kongu Engineering College, Tamilnadu, India. Email: vvenkates05@gmail.com*

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ABSTRACT

Satellite images with Very high range of spatial resolution gives the fine information of roads, vegetation and building areas. Shadows occur in these images are formed due to the elevated objects. These objects will block the light source to reach the destination. It is necessary to remove the shadows to get high quality satellite images. This paper presents a new shadow detection and shadow removal algorithm for optical satellite remote sensing images with less computational time and more accuracy. In the proposed method input RGB satellite images are transformed into HSV color space model and then shadows are detected using the Otsu thresholding method. After detection of shadows the non-shadow region around the shadow area is estimated. The mean and variance of the shadow free region is calculated and is compensated with the shadow region to remove the shadows. The experimental results shows the proposed shadow detection and removal approach can provide better recovered pairs of images using the stereo matching application before and after shadow removal.

Keywords: Shadow detection, thresholding, stereo matching.

1. INTRODUCTION

Remote sensing is the process of obtaining information and various details about an object or areas in the environment. In the remote sensing application various sensors are used to collect the data and that are analyzed to get information about the objects, area, etc. VHSR (Very High Spatial Resolution) optical satellite images are obtained from satellites like IKONOS, GEOEYE-1, and QUICKBIRD. These satellites mostly cover the urban areas. And the collected images may have shadows. In the satellite remote sensing images covering urban areas shadows are usually formed by elevated objects which include buildings, bridges, towers, etc. by blocking the light source. They cause problem in many applications like mapping, target detection and stereo correspondence process.

Therefore, it is necessary to reduce or to compensate the effect of shadows in order to get the fine information. Occurrence of shadows reduce the successful rate of various methods like edge extraction, object recognition, and image matching and change detection for the corresponding ground objects in the shadow [12, 14]. Several literatures have useful information about shape, relative position, surface character and other characters of object generating shadow [1,6,17]. Shadow detection and removal methods work together to remove shadows. They presented the technique for both VHSR and aerial satellite images and it can be categorized into method based on model and method based on shadow property [15][5][2][12][16].Spectral and geometrical features are used in shadow property based methods [4].Tsai gives a method using spectral images in HSI space to segment shadow [11] and also a method using thresholding saturation intensity difference in HSI color space [7]. After shadow detection, shadow removal can be done to eliminate the shadows and to restore the regions under shadow before using in any applications. Shadow compensation technique is used to compensate the shadow pixels and to restore the regions under shadows. Several algorithms include gamma correction method, linear correlation method, posteriori probabilities method [3,8,9] proposed that they are operate band by band in RGB color space, which makes the composite color unnatural [10] and another method using illumination chromaticity is proposed in [13] have several problems. To overcome these issues a new shadow detection and removal algorithm for optical satellite images is proposed. In the new method the shadows are detected using the Otsu thresholding algorithm after converting the RGB image into a HSV image. After detecting the shadows they can be removed by compensating the mean and variance of the non-shadow region with the shadow pixels in the shadowed region. The proposed shadow removal method is used in VHSR optical satellite images, particularly in urban zones. This method can be used in the application of stereo correspondence process to improve a result of a buildings stereo matching rate.

2. RESEARCH OBJECTIVE

The objective of this research is to present a new, simple, fast and efficient shadow detection and removal approach and to demonstrate its reliability on the application of stereo matching by comparing the correspondence images before and after shadow removal in urban pairs of IKONOS satellite images.

3. PROPOSED WORK

In the proposed method shadow is first detected using Otsu thresholding on HSV color space and removed using the non-shadow area around the shadow region.

An input RGB image with the shadows is converted into HSV color space which gives better spectral or color characteristics of image. After the conversion the shadow segmentation can be done using Otsu thresholding which detects only the shadow region. To remove the shadows, shadow compensation can be done by estimating the mean and variance of the non-shadow region (i.e. buffer area) found around the shadow region and then compensate with the shadow pixels. This method is applied in the stereo correspondence process to demonstrate the accuracy of this method before and after shadow removal. The proposed method is given in the form of flowchart and is shown in the Fig.1.

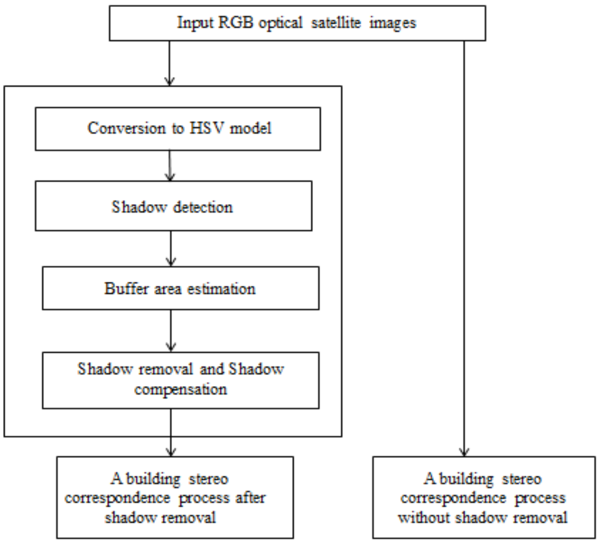


Fig.1: Approach used in proposed method

3.1. Shadow detection

The input RGB image is converted to HSV color model. HSV color model deals with Hue, Saturation and Value. HSV color model gives better intensity and color characteristics.

HSV color model has the following relations with the RGB model.

$$V = \frac{1}{3}(R+G+B)$$

$$S = 1 - \frac{3}{R+G+B}\min(R,G,B)$$

$$H = \begin{cases} \theta & if \quad B \le G \\ 360-\theta & if \quad B \ge G \end{cases}$$

where,

$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}(R-G)+(R-B)}{\sqrt{(R-G)^2+(R-B)(G-B)}} \right\}$$

After the conversion the shadow detection can be done using the Otsu thresholding algorithm which separates the shadow region and non-shadow region. Thresholding can be done at a predetermined level T according to the following equation,

$$I_{shadow}(i,j) = \begin{cases} 1 & if \quad I(i,j) \ge T \\ 0 & if \quad I(i,j) \le T \end{cases}$$

Thus the image obtained after this threshoding will be binary image with all the shadow pixels set to 1 and non-shadow pixels set to 0.The Fig.2(a) shows the input RGB image. The Fig.2(b) below shows the shadow detected image.

a. Input RGB image b. Shadow detected image

Fig.2 Shadow detection

3.2. Shadow Removal

In this shadow removal method shadows are removed and the surfaces under shadows are recovered using two steps.

3.2.1. Step 1: Buffer Area Estimation

In this process first the non-shadow region i.e. buffer area around the shadow region is estimated. This area is estimated using the morphological dilation process. The dilation process applied on binary images is used to enlarge the areas of foreground pixels i.e., white pixels at their borders Morphological dilation operation will expand the shadow boundaries and uses the structuring element to estimate the non-shadow area around the shadow pixels.

3.2.2. Step 2: Shadow removal

After estimating the non-shadow area around the shadow pixels i.e, buffer area, the mean and variance of that area is calculated. These values are then compensated with the mean and variance of the shadow pixels to remove the shadows.

The shadows are removed using the following transformation function,

$$I'_k(i,j) = \mu_{buff,k} + \frac{I_k(i,j) - \mu_k}{\sigma_{buff,k}}.\sigma_k$$

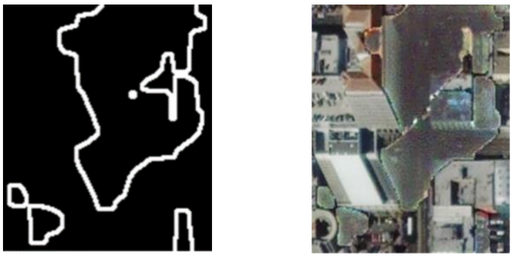
where,

$I'_k(i,j)$ is the compensated value of the shadow pixel

$\mu_{buff,k}$ and $\sigma_{buff,k}$ are the mean and variance of the pixels at the buffer area

μ_k and σ_k are the mean and variance of the shadow pixels

Thus the shadow is removed and the surface under shadows is recovered. The Fig.3(a) shows the buffer area around shadow region. The Fig.3(b) shows the image after shadow removal.



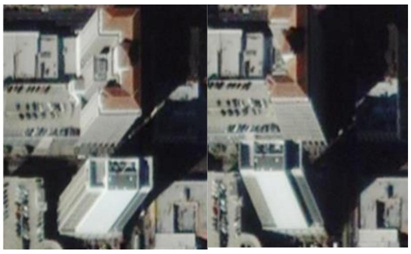
a. Buffer area estimation b. Shadow removed image

Fig.3 Shadow removal method

4. EXPERIMENTAL ANALYSIS

The experimental analysis is applied on the pair of stereo sample urban pairs of IKONOS images. Two pairs of images with less shadow and more shadows are taken. The proposed shadow detection and shadow removal method followed by stereo correspondence process is applied on both the pairs of images. This experimental analysis gives the accuracy of the proposed method after shadow removal.

The original pair of image having less shadow is shown in Fig.4 and the original pair of image having more shadow is shown in Fig.5. The recovered first shadow free pair and recovered second shadow free pair after removing the shadows is shown in Fig 6 and Fig.7



a) b)

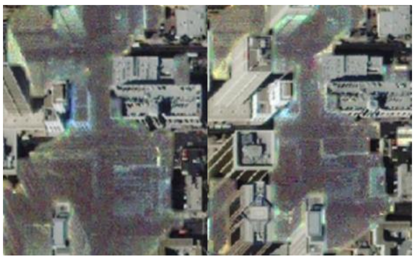
Fig.4 First pair with less shadow

a) b)

Fig.5 Second pair with more shadow

a) b)

Fig.6 First pair without shadow



a) b)

Fig.7 Second pair without shadow

Stereo correspondence process is applied on the original image and then to the recovered shadow free image to demonstrate the accuracy of the process. Before this process, fuzzy building extraction is done on the image to segment the building regions. After segmenting the building regions stereo correspondence process is applied on the image. Window matching technique is used in the stereo correspondence process. This window matching technique uses the square windowing. Left image is taken as a reference image and each pixel in the left image is compared with the right image. The matching pixels between two images give the matching rate of the pair of image. Hence, the matching rate is used to demonstrate the accuracy of the proposed method.

4.1. Before shadow removal

At first the stereo correspondence process is applied on the original pairs of image shown in Fig.4 and Fig.5. Fuzzy building extraction step is applied on both the pairs of images to segment the building regions. Later window matching technique is used on the images to calculate the matching rate. The Fig.8 and Fig.9 shows the fuzzy building extraction applied on original first and second pair and the window matching technique is used to calculate the stereo matching rate.

Fig.8 fuzzy building extraction on first original pair

Stereo matching rate for the original first pair: 54

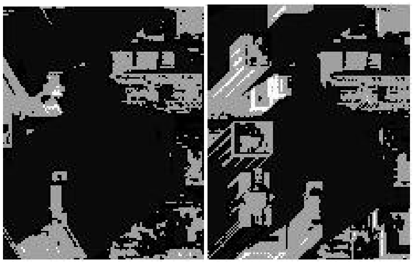


Fig.9 fuzzy building extraction on second original pair

Stereo matching rate for the original second pair: 37

4.2. After shadow removal

The stereo correspondence process is applied on the recovered pairs of image shown in Fig.6 and fig.7.Fuzzy building extraction step is applied on both the pairs of images to segment the building regions.

Fig.10 fuzzy building extraction on first recovered pair

Stereo matching rate for the shadow free first pair: 82

Fig.11 fuzzy building extraction on second recovered pair

Stereo matching rate for the shadow free first pair: 75

Later window matching technique is used on the images to calculate the matching rate. The Fig .10 and Fig.11 shows the fuzzy building extraction applied on the recovered first and second pair and the matching rate is calculated using window matching. The stereo matching rate after shadow removal i.e. shadow free pairs have more stereo matching rate compared to the original pairs .Thus, the stereo matching rate of these pairs of images before and after shadow removal gives the efficiency of the proposed method.

5. CONCLUSION

This paper gives new shadow detection and shadow removal method used in pairs of RGB satellite images IKONOS VHSR images are chosen as an example because those are one of the most common shadowed satellite images. A primary goal of the proposed method is to detect the shadows and to remove the shadows. At first, RGB image is converted into HSV model and then Otsu thresholding is used to detect shadows. This detection method doesn't require any priori information and it is simple and efficient. After that, shadow is removed by estimating the non-shadow area (buffer area) around the shadow region and compensating the mean and variance of that area with the pixels in the shadow region. The execution time of the detection and removal steps reaches 10.49 s for the most complicated shadowed pair. So, this method is fast and efficient. The simplicity, the fastness and the efficiency of the entire proposed approach are demonstrated by the experimental results using the stereo correspondence process.

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