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Object Oriented Shadow Detection and Correction by Image Inpainting in Remote Sensing Images

Divya S Kumar[1] and Neenu Wilson[2]

[1,2]Sree Buddha College of Engineering
E-mail: [1]divyasreekumar91@gmail.com, [2]wneenu@gmail.com

Abstract—*Satellite images provides rich information about earth resources. Remote sensing technology helps to derive these data. They have many applications in landscape, change detection, town planning etc. But, mainly in urban areas these images get affected by the shadows. The elevated objects are the reason for the appearance of shadows there. When the light source are blocked shadows are created. Shadows lowers the quality of images or it may affect the information provided by them. Thus for the correct image interpretation or to extract information it is important to detect shadow regions and compensate them. So far many algorithms and methods had been developed in shadow detection and removal. Most of them are based on pixel level detection and correction. An object oriented shadow detection and removal resolves the shortcomings of pixel level detection like losing of spatial information, mis-detection. Existing method suffers from color casting of images even after the shadow correction. A new method for shadow compensation by image inpainting resolves these color casting problem. Median diffusion inpainting is used here which takes less time and produce better results. As an extension change detection is also performed in these corrected images.*

1. INTRODUCTION

Satellite images gives significant level of information, which make them a valid and highly vital source for data gathering. One of the basic attributes of remote sensing images are shadows. Shadow detection plays an important role in digital aerial image processing. Shadows can be regarded as a type of useful information in 3-D restoration, height estimation and building location recognition. Shadow can provide geometric and semantic clues about the shape as well as height of its casting object and the position of the light source. Computer operations such as change detection, scene matching, and object recognition are greatly affected due to poor visibility in shadow regions.

Shadows are of two types one is self- shadow, which the shadow of subject is falling on the side of the image that is not directly facing the source of light. The other is the cast shadow, which is the shadow of subject falling on the surface of another subject because the first subject has blocked the source of light. The shadowing effect are commonly seen in regions where there are clear changes in surface elevation mostly in urban areas. The problem of shadowing is noteworthy in Very High-resolution remote sensing satellite images. It plays an important role in applications of urban high resolution remote sensing images like object classification, image fusion, change detection, and object recognition. Hence shadows need to be properly detected and corrected for the exact image interpretations.

A shadow is a region where direct light cannot reach due to obstruction by any object. Studies concerning shadow detection and removal have been going on in this field. Here are the basic assumptions of shadows

- The illumination image will be spatially smooth.
- Inside the shadow region no change in the texture of image
- Shadows are reflection image thus pixels inside the shadow regions contain different colors.

Shadow detection and correction is an important pre-processing or image enhancement step. In the shadow detection step we segment the shadow regions from the images where we have to work. Detecting shadow is important as the shadow correction is applied on this detected regions. In the removal stage the image is corrected or recovered from the defects caused by the shadows.

2. RELATED WORK

There were many effective shadow detection algorithms. An invariant color model [1] is used to identify and classify shadows. Shadow candidate regions are extracted first and by using the invariant color features the candidate pixels are classified as cast shadow or as self-shadow points. The shadow areas are estimated according to the space coordinates of buildings which is calculated from digital surface models and also by the altitude and azimuth of the sun. Thus for the accurate identification of shadow, the threshold value is obtained from the estimated grayscale value of the shadow areas

The properties of shadows in their luminance and chrominance space are exploited in [2]. The method is applied in several invariant color spaces, including HCV, HSV, HSI, luma, inphase, and quadrature (YIQ) and YC C models. First the RGB aerial color images are transformed into the invariant color models. Shadow regions are remarkable with increased hue values. For each pixel ratio of Hue over intensity is taken. Thus a ratio image is constructed. Over the histogram distribution of the ratio image an Otsu's method is applied and the threshold for segmenting the regions are determined. To compensate shadow regions from their neighborhoods a two-step histogram matching technique is used.

For accurate shadow detection, instead of using global thresholding scheme a successive thresholding scheme is used in [3]. A ratio map is constructed by the color transformation method explained in [2] and modified by applying exponential function so that the difference between shadow and non-shadow pixels stretches. By applying the global thresholding process the input image is separated into candidate shadow pixels and non-shadow pixels and by using the connected component analysis they are grouped to form candidate shadow regions. Local thresholding process is applied to each region iteratively to detect true shadow pixels from candidate shadow pixels.

Lorenzi [4] proposed a new approach in which shadow areas are detected and classified by means of state of the art support virtual machine. Classifiers (SVM) are trained to detect illumination pairs based on many features. They include comparing the ratio of their intensities, color and texture histograms, their chromatic alignment and their distance in the image. The reconstruction is based on linear regression method by adjusting the intensities of the shaded pixels according to the statistical characters of the corresponding non shadow regions. Apart from pixel or edge information a region based approach is used in [3]. Using graph cut inferences the regions are classified as shadows and non-shadows.

Compared to non-shadow regions, shadow regions possess lower brightness and also have slow gradient change in luminance value. This gradient values of shadow regions are used for shadow detection method based on partial differential equations (PDES) [5]. The algorithm takes the gradient values as parameter of edge detectors. This controls the speed of diffusion of PDES. The calculation is an iterative process. During calculation to protrude shadow regions the algorithm conceal changing pixel values of the non-shadow regions.

In [6] a methodology to automatically detect and remove the shadows in high resolution urban aerial images for urban GIS application is explained. Shadow computation is done by locating shadow in the RGB image by photogrammetric engineering using camera model and digital surface model and based on it shadow areas and its corresponding bright areas are segmented and labelled by image analysis. The cast shadow will be traced to determine if they are visible in the projection image. An iterative tracing scheme is used. Statistics of shadow areas reflects the distribution of intensities of the shadow. In image histogram the local minimum value which is close to reference threshold is taken as the threshold for the fine segmentation. Shadow removal include deciding the companion area to the shadow area. From the edge of the shadow area pixels along with shadow direction within a certain distance are taken as companion area. After that compute the statistics of the two region and map shadow intensities to their companion intensities

A different object oriented shadow detection and removal technique is explained in [7]. During image segmentation shadow features are considered and according to the statistical features of the images shadows are extracted. According to object properties and spatial relationship between objects, some dark objects which could be mistaken for shadows are ruled out according to object properties and spatial relationship between objects. Shadow removal is done by inner-outer outline profile line (IOOPL) matching. The homogeneous sections are attained through similarity matching and shadow removal is performed according to them. Then calculates the radiation parameter according to the homogeneous points of each object and then applies the relative radiation correction to each object.

Aforementioned methods really deals with pixels of the images. In pixel level shadow detection some useful spatial information is lost. There is a possibility that noise and dark pixels be mistaken as shadows. Images are converted into different invariant color spaces to obtain shadows. The pixel intensity value is susceptible to illumination changes which leads to less accuracy and efficiency. Due to the shortcomings of shadow detection discussed earlier, we propose a new technique an object-oriented shadow detection and removal method.

3. OBJECT ORIENTED SHADOW DETECTION AND CORRECTION BY IMAGE INPAINTING

The Fig. 1 gives the flowchart of the proposed system. The procedure mainly follows four steps.

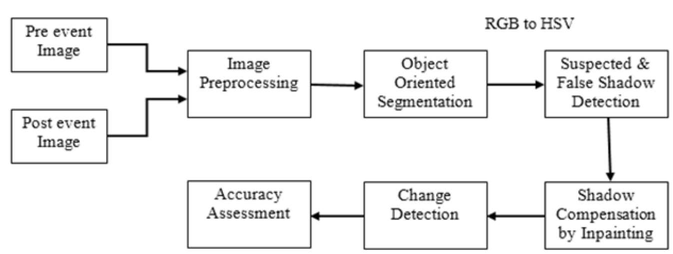

Fig. 1 Flowchart of the procedure

Proposed Algorithm

Step 1: Input prevent and post event image
Step 2: Image registration by combining correlation and entropy based

Step 3: Shadow Detection

i. Segmentation of both images by active contour method
ii. Suspected shadow detection by transforming into HSV space
iii. False shadow elimination

Step 4: Shadow compensation by median diffusion based inpainting

Step 5: Change Detection

i. Image Ratioing producing change map C1
ii. Watershed Segmentation producing change map C2
iii. Combine C1 and C2 to produce the final change map C

3.1 Image Preprocessing

The preprocessing is a common name for operations with images at the lowest level of abstraction. Both input and output are intensity images. The aim of preprocessing is an improvement of the image data that it suppresses unwanted distortions or enhances some image features. Here the preprocessing steps include image registration, histogram equalization, filtering. Image registration is the process of aligning two or more images of the same scene. The process involves designating one image as the reference and applying geometric transformations to the other images so that the previous align with the reference Histogram equalization is a technique for adjusting intensities to enhance contrast. Also filtering is applied to remove any speckle noises if present.

3.2 Shadow Detection and Removal

3.2.1 Shadow Detection

The proposed system performs shadow detection and analysis on individual objects. So, the first step is segmentation into individual objects using active contour segmentation using level set. The segmented RGB image is converted into HSV so that shadows are easily detected. HSV try to capture the components, the way we humans perceive color. Often we want to separate color components from intensity for robustness to lighting changes, or removing shadows. If RGB is used, a high threshold will be needed to accommodate to this difference. There are more chances of false positive errors in algorithms using RGB color space. In HSV spaces, the chromaticities of the pixels in the image have a high value of saturation. Thus suspected shadow detection is very easy.

Suspected shadow detection includes determining a threshold value and using this threshold to determine whether shadow is casted on an object or not. To find threshold for shadow detection bimodal histogram splitting provides a feasible way, and the mean of the two peaks are adapted as the threshold.

3.2.2 Elimination of False shadow

False shadow elimination is performed in these suspected shadow areas. Dark objects may be misdirected as shadows. Thus inorder to remove these dark objects from the suspected shadows more accurate shadow detection results are needed. By calculating the correlation between the dark object and the linked objects they can be solved. Vegetation and water bodies can also be misclassified as shadows. This can be ruled out by considering the blue and green waveband properties in HSV space.

3.2.3 Shadow Compensation

Shadow compensation is to recover the shadow areas in an image. Shadow compensation is done by performing image inpainting. In inpainting the surrounding patches are used for replacing the shadow patches as such. So, there will be no color casting, which was one of the main disadvantage of the existing method. Median diffusion based inpainting is used here. The technique uses median filter which is one of the most popular nonlinear (order statistics) filters.

The inpainting algorithm proceeds by initially identifying the inner and outer object areas. The shadow pixel are then recovered by diffusing median value of pixels from the exterior region into the inner region to be inpainted. The inpainted image pixel is represented as:

I (i, j) = median (I (x, y))

where x = i − D2 : i + D2 and y = j − D2 : j + D2.

The parameter D is chosen to be almost equal to the width of the inpainting area.

The detailed inpainting algorithm is given below,

Start

Select the parameter *D*

For every pixel *(i, j)* belonging to the shadow area _

Select Range = *((i − D/2: i + D/2), (j − D/2 : j + D/2))*

R = *I (*Range, red*)*, *G* = *I (*Range, green*)*, *B* = *I (*Range, blue*)*

Apply median filtering:

R = median*(R)*, *G* = median *(G)*, *B* = median *(B)*

Diffuse *(i, j)* pixel of *I* with [R, G, B]

I (i, j) = [*R*, *G*, *B*]

For all pixels *(i, j)* ∈ to the inpainting area repeat above steps

End.

Here, inpainting is regarded as median filtering, a nonlinear order statistics filtering. The median is the most probable estimate (MLE) of location for the Laplacian distribution. Hence using the median diffusion method gives better estimate of the pixel I (i, j) compared to existing inpainting methods

Existing inpainting techniques are very time consuming and tends to produce incorrect results. The proposed median diffusion inpainting method for shadow removal takes very less time and produces far better results than the existing techniques.

3.3 Change Detection

As an extension to the shadow detection and removal, change detection is added to the procedure. The pre event and post event images are needed for performing the change detection. The shadow corrected images obtained previously are used for change detection in urban areas. Shadow correction plays a vital role here, as the presence of shadows can lead into incorrect change detection.

Change detection concerns with detecting whether or not a change has occurred. It describe, and evaluate differences between images of the same scene which is taken at different times or under distinct conditions. There are many existing change detection methods. But each method when used independently produces unsatisfactory results. Therefore the proposed change detection uses a hybrid change detection technique combining the existing change detection techniques, thus exploiting the advantages of each method. In this paper a combination of modified image ratioing and watershed segmentation is used.

Image Ratio: During change detection process, there is a chance of misinterpreting rough textured area as scrap areas. To tackle this problem GLCM feature dissimilarity (DIS) is calculated.

Watershed segmentation: Segmenting an image is one of the important pre analysis tool, especially for images of very high resolution. After segmenting correlation coefficient of two image segments are calculated. Segments with a high correlation denote no change while regions with a low correlation represent changes.

3.4 Evaluation

Evaluation of both shadow removal and change detection method is performed in this paper.

3.4.1 Shadow Analysis:

The analysis is performed by comparing the shadow removed region and the non-shadow region. For each object the pixels belonging to shadow area, non-shadow area, and shadow removed area are collected and then mean average value and standard deviation are calculated. The average value and standard deviation of the shadow-removed region are close to that of the non-shadow region.

3.4.2 Change Detection Analysis:

This is performed to calculate the accuracy of the proposed change detection method. This includes the comparison of ground truth value with the obtained change map and plotting the confusion matrix. It was found that the proposed method produced 86% accuracy. The proposed method was also tested against image difference, image ratio and CEST [8] method and the results show that our method produces better result than existing change detection techniques.

4. RESULTS AND DISCUSSIONS

Subjective Evaluation

Fig. 2 shows shadow removal applied to two test images. Visual comparison of the results show the effectiveness of the proposed system.

Fig. 2: Shadow compensation by existing and proposed method.

Fig. 3 shows the result of the proposed change detection applied to a study site

Pre event image **Post event image** **Change Map**

Fig. 3: Change Detection by proposed method

Objective Evaluation

Numerical analysis of shadow removal and change detection are shown below in tables I and II respectively

Table I: Numerical Analysis of Shadow Removal

Image Areas	Area Size	Existing		Proposed	
		Average	Standard Deviation	Average	Standard Deviation
Non Shadow	2224	141.96	96.32	141.96	96.38
Shadow	2224	66.58	134.85	66.58	134.85
Shadow Removed	2224	151.81	51.61	137.51	112.07

Table II: Accuracy measures of change detection methods

Change Detection Methods	Image Difference	Image Ratio	CEST	Hybrid Method
Accuracy Measures	76. 48	85.92	84.45	88.66

The above numerical analysis proves the efficiency of our proposed shadow removal and change detection methods.

5. CONCLUSION

There are various methods for shadow detection and removal methods. Many of them deals with pixels of the images. In pixel level shadow detection some useful spatial information is lost. There is a possibility that noise and dark pixels be mistaken as shadows. Thus came the object oriented shadow detection and removal. But in the existing method even after the shadow removal color casting of the image is a problem. This problem can be effectively resolved by image inpainting as this method fills holes in the image by searching for similar patches in nearby areas. An important property needed during inpainting is the preservation of edges which the median filter do well. The proposed change detection technique that uses a combination of existing change detection methods produces better change map. The new method is compared with existing techniques and found that our method produced an accuracy of 86% compared to other techniques.

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