A Survey on Shadow Detection and Removal of Satellite Images

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Abstract— The presence of shadows in satellite images can occlude some objects to cause partial or total reduction or loss of their information. In order to recover the occluded information of objects, shadow removal is a significant process for the image interpretation. It's not quite easy to remove the shadows of satellite images particularly high resolution satellite images. There are so many existing methods for shadow detection and removal for satellite images. The most significant methods include object based method, object oriented shadow detection and removal, on-local regularized shadow removal and Shadow detection and removal of satellite images using linear correlation and patch intensity difference mapping.

Keywords: SANS (Spatial adaptive non local sparse), linear correlation, patch intensity, NL operators, IOOPL matching

I. Introduction

Satellite imaging is essential for the observation and research of space, earth and other planets has ability to obtain very high-resolution images. These high-resolution images exhibit more detail information to increase the object-oriented application potential, e.g., a building location, to spot out populated and non-populated areas. Many effective algorithms of shadow removal have been proposed for natural images or remote sensing multispectral images. However, there is a great lack of shadow removal method for panchromatic imagery, while these panchromatic images usually contain high resolution data to be useful for various applications. For the purpose of the information recovery of obscured objects, the characteristics of shadows and objects in the panchromatic images of urban areas should be analyzed and remove the shadows to obtain shadow-free images. Many current researches and studies indicate that shadow detection is the indispensable step in the complete processing chain of shadow removal.

The object based [3] method is used to extract shadow areas from image using brightness value. Object oriented shadow detection and removal [5] utilizes IOOPL generation and matching which contains exact inner and outer outlines the boundary of shadows. In SANS model [1], linear radiometric correction and nonlocal sparse model are used to simultaneously control the brightness and smoothness of the recovered shadow areas to be the same as the corresponding non shadow areas based on group matrix with similar patches. An adaptive nonlocal regularized shadow removal method [4] new shadows removal method for aerial images, using nonlocal (NL) operators.

II. Related works

A. Object-based shadow extraction and correction (Liu's method).

Object based method is used to extract shadow areas from image using its brightness value. The pixels are grouped into objects on the basis of four parameters. They are scale, color, smoothness, compactness etc. Initially images are segmented and then objects are classified into sunlit and shadow regions from the histogram. Results after classification are improved by utilizing the neighbor relationship.

The pixels in the satellite image were grouped into objects using a heuristic algorithm for image segmentation, in which objects are recognized in terms of our parameters: scale, color, smoothness, and compactness.

The scale parameter determines the maximum allowable heterogeneity within an object .In general, the objects size increases with an increase in the maximum allowable heterogeneity. Color is a vital parameter for creating meaningful objects. The factors of smoothness and compactness are used in order to optimize image objects to create smooth or compact borders. Color, smoothness, and compactness are general variables that are used to optimize an object's spectral homogeneity and spatial complexity.

B. Object oriented shadow extraction and correction (Zhang's method).

In this method, according to the statistical characteristics of the images, suspected shadows are extracted, sometimes dark objects which could be mistaken as shadows are removed on the basis of object properties and spatial relationship between objects. Image segmented by thresholding method and shadows are detected. IOOPL matching is used for shadow removal. First, the IOOPLs are obtained with respect to the boundary lines of shadows. Then shadow removal is performed on the basis of homogeneous sections obtained through IOOPL similarity matching. IOOPL matching is a procedure of obtaining homogeneous sections by making similarity matching to the IOOPL section by section which is shown in the fig 1. During this process, Gaussian smoothing is performed to simplify the view of IOOPL sections.

The IOOPL is divided into sections to rule out the non-homogeneous sections with that same standards, and then, the similarity of each line pair is calculated section.

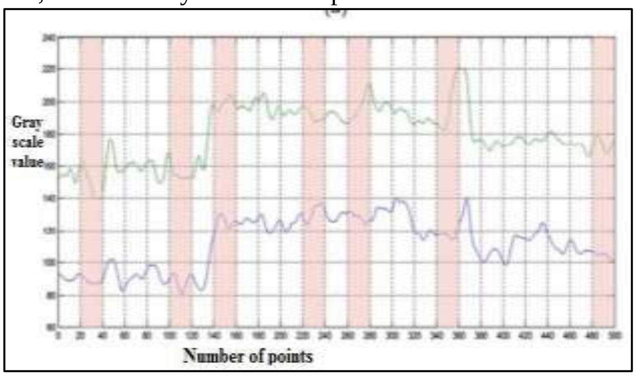


Fig. 1: IOOPL matching

Here Penumbra areas are handled well, but boundaries are not clear. There is a failure to control smoothness of recovered shadow area. The restored shadow areas are noisier.

In fig 2, R is the vector line of the shadow boundary got from shadow detection, R1 is the outer outline in the non-shadow portion, after expanding R outward, and R2 is the inner outline in the shadow portion by contracting R inward. There is a one-to-one correspondence between nodes on R1 and R2. When the correlation between R1 and R2 is so close, then there is a large probability that the location belongs to the same type of object

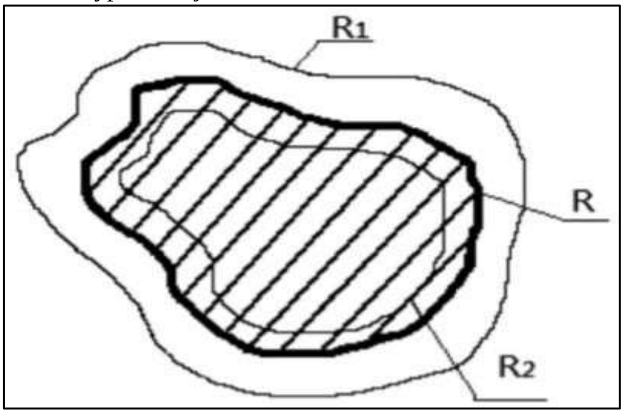


Fig. 2: Diagram of shadow boundary, inner, and outer outline lines

Here Penumbra areas are handled well, but boundaries are not clear. There is a failure to control smoothness of recovered shadow area. Restored shadow areas are noisier.

C. Adaptive nonlocal regularized shadow removal method (Li's method).

This is another shadow removal method for satellite images, using nonlocal (NL) operators. In this method, the soft shadow concept is introduced to replace the hard shadow. NL operators are utilized to regularize the shadow scale and the updated shadow-free image. The spatially adaptive Non local regularization is introduced to handle compound shadows. The combination of the soft shadow and non-local operators yields shadow-free results.

Here shadow removal involves two procedures, i.e., detection and compensation. The shadow detection (SD) methods can be classified into two types, unsupervised detection and supervised detection. It doesn't need any samples for unsupervised detection, as the shadows are extracted by some prior characteristics, such as low intensity in a single-band image. Image matting is used for effectively detecting soft shadows, and the non-local regularized SC yields satisfactory shadow-free results. The first NL operator, regularizing the shadow scale, which preserves the edges and the textures in the shadow regions. k- Means clustering can be used to distinguish different land surfaces restores clear boundaries. The first NL operator and second NL operator are combined to avoid over smoothing in the umbra and under smoothing in the penumbra.

D. Shadow detection and removal of satellite images using linear correlation and patch intensity difference mapping

This scheme [6] involves the two main procedures as shown in Fig 3: shadow detection and shadow removal. In the detection step, we present a soft shadow detection method by multilevel image thresholding and image matting technique. The detection mainly contains three steps. Initially, the shadow image is classified to shadow and non- shadow areas roughly by hard threshold value.it results a binary map (hard map). The hard map of binary mask cannot provide the precise edges between the two areas, due to the presence of penumbra. So that, the shadow areas are eroded and dilated by morphological operators and the difference middle areas are filled with the original image. Then the image matting method is employed to calculate the shadow coefficient for each pixel based on the mask image. 0 is shadow, 1 is non-shadow, and the penumbra area is from 0 to 1 to indicate the shadow probability.

In the removal step, a novel shadow removal framework is used which is divided into two levels: the initial removal and the refined removal. In the initial removal level, the linear correlation method is employed to enhance the shadow area. Second level is the refined restoration process; obscured information of objects in the shadow areas is recovered precisely by the unit of patches based on the patch intensity difference.

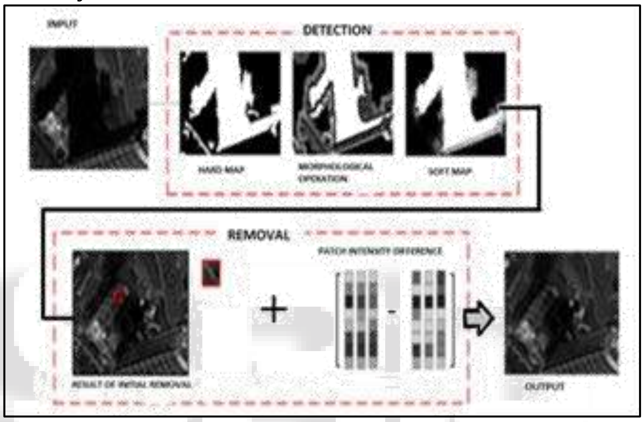
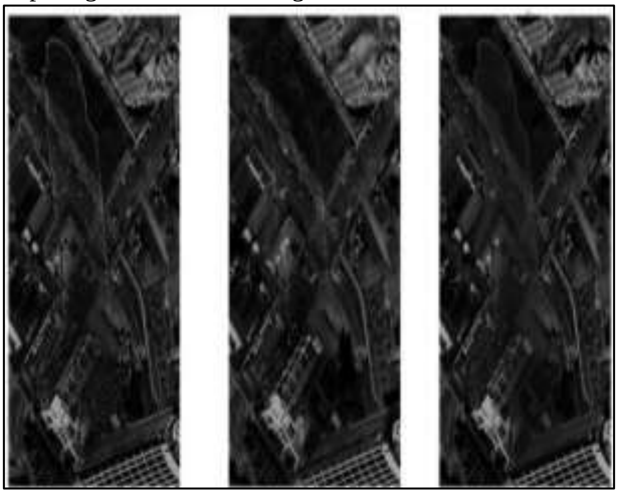


Fig. 3: Architecture diagram of Shadow detection and removal of satellite images using linear correlation and patch intensity difference mapping

	MEAN VALUE	STANDARD DEVIATION
Corresponding non-shadow area.	53	6.1
Recovered shadow area by Liu's method.	61	21.2
Recovered shadow area by Zhang's method.	60	15.4
Recovered shadow area by Li's method.	58	9.0
Recovered shadow area by patch intensity difference mapping method.	55	6.9

Table 1: Comparing the mean value and standard deviation of the recovered shadow area samples by three methods to that of corresponding non-shadow area

Finally the shadow free image is smoothened by applying Gaussian filter to obtain smoothened shadow free image. The advantages of this system are soft shadow detection avoids the boundary lines between original shadow and non-shadow areas. The smoothness and brightness of the recovered shadow area are of the same as that of the non-shadow area. It also avoids the recovered shadow area noisy and overexposed and gives good performance while comparing with other existing methods described above.



(a) (b) (c)

Fig. 4: Results of shadow removal by different methods. (a) Result of Liu's method, (b) Zhang's method, (c) Li's method

Fig. 5: Results of shadow removal by using linear correlation and patch intensity difference mapping

III. CONCLUSION

Different types of shadow removal methods for panchromatic satellite images like Liu's method, Zhang's method, Li's method and patch intensity difference mapping has been explained and discussed. In the Table 1 their performances are compared on the basis of mean value and standard deviation of recovered shadow samples. In fig 4 and fig 5 the results of shadow removal by different methods can be seen and from that this can be concluded that shadow removal using linear correlation and patch intensity difference mapping is found better than other methods.

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