# SHADOW DETECTION AND REMOVAL OF PANCHROMATIC SATELLITE IMAGES

**Amrutha Vishnupriya S[1], Vicky Nair[2]**

*[1] P G scholar, Dept. of Computer Science And Engineering, Musaliar College of Engineering and Technology, Pathanamthitta*

*[2] Associate professor, Dept. of Computer Science And Engineering, Musaliar College of Engineering and Technology, Pathanamthitta*

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**Abstract** - *The existence of shadows in panchromatic satellite images can occlude some objects in images to cause the reduction or loss of their information, particularly in urban scenes. Shadow removal is a significant processing procedure for recovering the occluded information of objects, which is useful for many object oriented applications. This system is a novel framework of shadow detection and removal for panchromatic satellite images to restore the obscured object information. In shadow detection module , hard shadow detection and soft shadow detection method are used by the combined application of a multi - thresh holding method and image matting technique. Soft detection results can show both umbra areas and penumbra areas to describe the shadow distribution precisely and this result is used for removing the detected shadow in two levels. In the initial correction of shadow removal, the linear correlation is used to enhance shadow areas roughly in global.*

*In the second level refined process, the characteristics of intensity of objects and shadows are noted and patch intensity difference is calculated and it is used to remove the shadow portion. The linear radiometric correction and intensity adjustment are used to control the brightness. Finally the shadow free image is smoothened by applying Gaussian filter.*

***Key Words*: Gaussian filter, Image matting, linear correlation method, Panchromatic satellite images, Penumbra, Soft shadow detection, Umbra.**

## 1. INTRODUCTION

The high resolution Satellite imaging is recommended and necessary for the observation 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 applications, like building detection and to spot out populated and non-populated areas. Unfortunately, most of the high-resolution satellite images contain shadows as undesired information which causes partial or total loss of information. In such a circumstance, the objects in the shadow regions are difficult to be extracted for further processing or applications. So, in order to restore obscured objects, shadow detection and shadow removal is an essential preprocessing step for panchromatic high-resolution satellite images. 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.

In the proposed system, build a novel shadow detection and removal method has been developed for the panchromatic satellite images.Multilevel image thresholding method and image matting technique are both used to auobtain soft shadow detection results. In the initial step of shadow removal, the linear correlation method is used to enhance shadow areas roughly in global. In the second level refined process, the characteristics of intensity of objects and shadows are noted and patch intensity difference is calculated and it is used to remove the shadow portion. The linear radiometric correction and intensity adjustment are used to control the brightness. Finally the shadow free image is smoothened by applying Gaussian filter to obtain smoothened shadow free image.

## 2. PROPOSED METHOD

The proposed scheme involves the two main procedures as shown in Fig. 1: 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, we propose a novel shadow removal framework 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. In the following sections, the detail of the algorithm is provided.

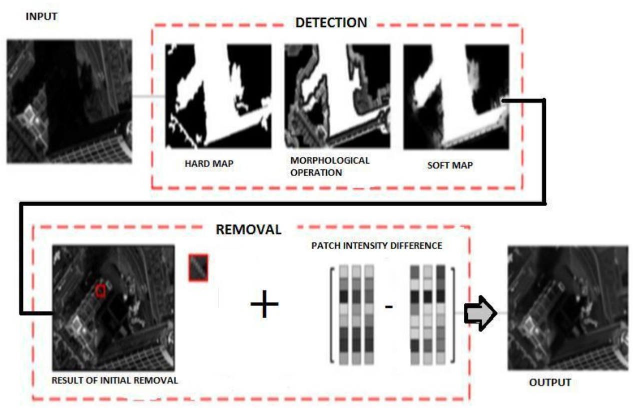


**Fig -1**: Architecture of proposed system.

### 2.1 Shadow detection

Shadows are formed because of something blocking the light source, as shown in Fig. 2. The phenomenon frequently occurs in dense urban areas. Solving the shadow problem is very important issue for urban object applications in the high-resolution satellite images .Shadows can be classified into self-shadow and the cast shadow. The self-shadow is formed when a face of the object is not directly illuminated by the light. The cast shadow is formed when some objects block the light source to fall on other objects. And the cast shadow is of two types: the umbra and the penumbra. The umbra is not directly illuminated by the light source , while the penumbra is only partly blocked by light source. The penumbra is obvious in very high-resolution images. In addition to shadow areas, other areas under the direct light are called non shadow areas or sunlit areas in this paper. In this work, we mainly research the cast shadow areas, and distinguish the umbra and the penumbra in the shadow detection.

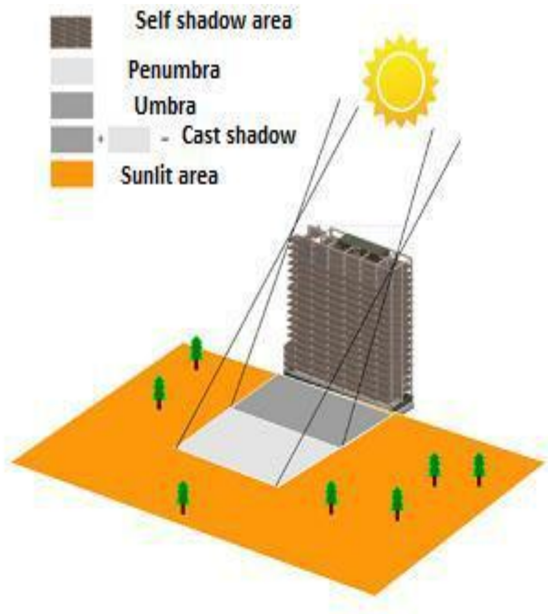


**Fig -2**: Formation of shadow.

#### 2.1.1 Hard shadow detection

Initial detection is used to locate the shadow areas. Shadow image is classified to shadow and non -shadow areas roughly by hard threshold. Multilevel image thresholding is used as thresholding method here. the result of hard thresholding is a binary image which is called hard map, shown in the fig 3.

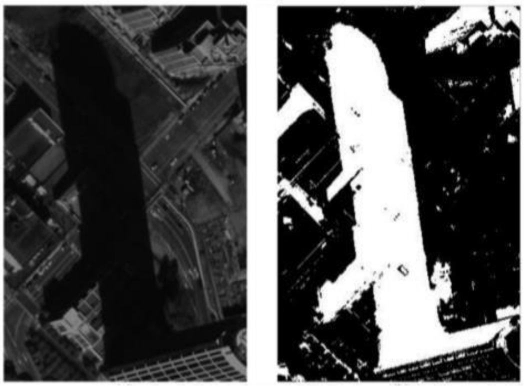

**Fig -3:** Result of hard shadow detection

### 2.1.2 Applying morphological operations

The hard map of binary mask cannot provide the precise edges between shadow and non- shadow regions due to the presence of penumbra. So two morphological operations are applied to shadow areas. They are erosion and dilation. Erosion removes pixels on the object boundaries and dilation adds pixels to the boundaries of objects in an image.

These morphological operations are applied to locate penumbra. Shadow areas are eroded and dilated by these two morphological operators and the difference middle areas are filled with the original image.

$$Diff[x,y] = d(Bm[x,y]) - e(Bm[x,y])$$

where Diff represents the difference image between dilation and erosion; d and e represent dilate and erode operations.

**Fig- 4:** Result after applying morphological operations.

### 2.1.3 Soft shadow detection

An image matting technique is used to derive the probability value of each pixel belonging to the shadow or non-shadow.0 and 1 represent the pixel belonging to non-shadow and shadow respectively. If the value is between 0 and 1 then pixel belonging to the penumbra in the soft shadow map. Image matting can accurately separates the foreground image from background image, representing shadow, and non-shadow.

Image matting technique calculate the shadow probability θ for each pixel by minimizing the energy function based on the following,

$$E(\theta) = \theta^T L\theta + \lambda(\theta - \hat{\theta})^T D(\theta - \hat{\theta})$$

where θ is the predicted shadow probability represents laplacian matrix and D is a diagonal matrix. By all the above steps shadow detection process is completed. The detected shadow is yet to be removed next.

## 2.2 Shadow removal

The proposed removal method including two levels is the initial shadow removal or correction using linear correlation and final refined restoration with smoothening. The initial correction step compensates the intensity for shadow area by a global parameter, which makes the same brightness and smoothness across shadow area and non-shadow area belong roughly to the same category. The refined restoration step utilizes the patch intensity difference between the initial corrected image and non-shadow region to restore the shadow areas making same brightness and smoothness as that of non-shadow area.

### 2.2.1 Initial Shadow removal

After soft shadow detection initial shadow removal is performed. Here linear correlation correction is used for restoring the brightness of shadow region. This procedure uses the mean value and standard deviation of all the sunlit areas to compensate the intensity of shadow areas in the whole image. The shadow-free image after initial shadow removal can be expressed as,

$$I_n[x,y] = (1-\theta[x,y])I_s[x,y] + \theta[x,y] \times \left(\frac{\sigma_{\text{sunlit}}}{\sigma_{\text{shadow}}}(I_s[x,y] - \mu_{\text{shadow}}) + \mu_{\text{sunlit}}\right)$$

where ,In is the intensity of shadow after the initial correction; Is is the intensity of shadow in the original shadow image; θ is the shadow probability of our soft detection. μ shadow represents the mean value of shadow areas ,μsunlit and μshadow implies mean value of non-shadow area, σsunlit and σshadow represents the mean value and standard deviation of shadow areas and non-shadow areas.

### 2.2.2 Refined restoration and smoothening

Initially restored shadow areas can be still noisy and non- uniform. So we recover the shadow area in detail with the information of the intensity. It makes uniform image quality between the recovered shadow areas and the non-shadow. For that initially we take the initially corrected image and non -shadow region and are divided into patches. Each patch has its own intensity. Patch intensity of corrected image is compared with patch intensity of non- shadow region. If the image patch intensity is less than non- shadow patch intensity, then patch intensity difference is calculated,

Id = I[i]ns - I[i]im

Where I[i]ns represents the patch intensity of non-shadow region and I[i]im represents the patch intensity of initially corrected image. This intensity difference is added to each shadow patch to adjust the shadow region of the image. Then shadow and non -shadow regions are separately adjusted with the computed value of Id .

After removing shadow in two levels, it is smoothened using Gaussian low pass filter. It is a final touch given to the shadow free image. Gaussian smoothening is used here to reduce the noise of image by applying Gaussian low pass filter. This smoothening obtains smoothened shadow free image.

**Fig-5**: finally smoothened shadow free image.

**Table – 1:** The mean value and standard deviation of the recovered shadow area samples by to that of corresponding non-shadow area

| | MEAN VALUE | STANDARD DEVIATION |
|---|---|---|
| Non-shadow region. | 53 | 2.5 |
| Recovered shadow area by our proposed method. | 60 | 3.9 |

For quantitative analysis the samples of the recovered shadow areas are selected and the samples in the corresponding non- shadow areas are collected, and the mean value and standard deviation of both samples are computed. If the mean value and standard deviation are closer to those of non-shadow area samples, which indicates that the method is better. As can be seen from Table I, proposed method performed better. The results indicate that the proposed method can promise the brightness (mean value) and the smoothness (standard deviation) of recovered area to be the more or less similar to that of the similar non-shadow area. Efficiency of the system can also be estimated by computing no of shadow pixels removed out of total no of detected shadow pixels.

## 3. CONCLUSION

A novel framework for shadow detection and shadow removal method for the very high resolution panchromatic satellite images is proposed. This work has dealt with the challenging problem of the shadow removal in the panchromatic satellite images, to recover the obscured information of objects in the shadow containing images. For shadow detection, multilevel image thresholding and image matting technique are combined to obtain the soft detection results. The soft shadow detection results can show the probability value of each pixel belonging to the shadow, and helps to trace out the presence of penumbra portion. To restore the occluded information of objects, two levels of removal methods including the initial correction and the refined restoration are used. The initial correction step compensates the intensity for shadow areas by global

parameter. In the refined restoration step utilizes the patch intensity difference between the initial corrected image and non-shadow region to restore the shadow areas making same brightness and smoothness as that of non-shadow area
. From the experimental results, our method to solve the main problems is summarized as follows:

The soft shadow detection is performed automatically. The shadow probability is calculated accurately to show the distribution of umbra and penumbra. The proposed automatic method is effective to avoid the boundary effects after recovery, due to the presence of the penumbra.

The proposed shadow removal method can restore the obscured information of objects in shadow areas effectively as comparing with existing methods. The shadow areas are restored by patch intensity difference and the brightness also adjusted, finally results are smoothened to reduce the noise.

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