A Novel Shadow Removal Algorithm Using Niblack Segmentation in Satellite Images

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***Abstract*—Shadow is formed by the interaction of light with object. Effect of shadow is very crucial in the case of satellite image processing. Roads, buildings, trees etc are detected for various applications. But the interference of shadow makes mismatching of these objects. Several algorithms are being developed to detect and reconstruct the shadow region. This paper presents a Shadow detection technique based on Niblack segmentation. Niblack segmentation gives better shadow regions compared to Otsu's thresholding method and Sauvola based thresholding. Reconstruction of the shadow region is done by the Bayesian classifier. This classifier generate a training vector and reconstruct non shadow region from shadow region. Posterior probability is determined to reconstruct the non shadow image intensity level. This algorithm is successfully tested with VHSR images.**

***Index Terms*-Satellite image processing, Markov random field, shadow detection shadow reconstruction, Bayesian classifier, Niblack Segmentation,Morphological operations**

I.INTRODUCTION

A shadow is formed when an illuminating light source is obstructed by an object. However, the shadow regions are illuminated by surrounding light. A shadow could be divided into two types: Self shadow and Cast Shadow. In self-shadow, the shadow region is on the object itself whereas in a cast shadow, the shadow is on the background or on other objects. The cast shadow may be further classified into two: Umbra and Penumbra. Umbra represents the shadow region where the light source is completely hidden and penumbra is the region around the edge of the shadow where the light source is only partially hidden [1]. The width of penumbra varies with the height of the object and elevation angle of the sun.

Very High spatial Resolution (VHSR) satellite images are very much used in the remote sensing field [9]. A wide verity of applications like change detection, weather forecasting etc are used with satellite imagery. These images give very minute details of bridges , trees, building[6] etc. VHSR images have some drawbacks like the presence of shadows, it is very common in urban areas where the surface elevation changes is very large and length of shadow is very high.

Mostly used methods for detection of shadows are Thresholding technique [2], Image based methods, Colour Spectrum based techniques and Texture based techniques [3]. In threshold based technique, shadow and non-shadow pixels are determined by using a predetermined threshold level where threshold value is set based on histogram splitting method. In image based techniques, shadow properties like intensities, edges, umbras are made use ofThe pixel value of shadow portion is very low and it has dark colour compared to their surroundings so it become easily noticeable and thus, its properties can be collected [7]. Colour spectrum based techniques are based on the colour property of images after investigating saturation-value (HSV) of cast shadow. The shadow changes the hue component slightlyand decrease saturation component. In texture based techniques, the basic idea is that the texture of foreground pixel is different from background but texture of shaded area remains same [5]. For change detection canny edge maps are generated. For detecting shadow blackbody radiator method is also used [4].

To reconstruct the detected shadow areas three algorithms can used such as gamma correction method, the linear-correlation method, and the histogram matching method [14]. Gamma correction method considered shadow as multiplicative source that destroy the brightness of underlying pixels and built the relationship of shadow and non shadow pixel by power

function. In linear correlation method, shadow is modelled as an additive and multiplicative noise and then non shadow pixels are reconstructed by linear correction function. In the histogram-matching method, the histogram of the shadowed region was matched to that of the non shadow area of the same class in a window.

For a given shadow region R_s , want to estimate the non shadow region R_n.It is a maximum posteriority problem P(Rn |Rs),which can be expressed as

$$Rn'=\arg\max P(Rs\,|\,Rn) \qquad (1)$$

According to Bayesian theorem, P(Rn |Rs) is described as,

$$P(Rn\,|\,Rs)=P(Rn,Rs)\,|\,P(Rs) \qquad (2)$$

where P(Rn,Rs) is the joint probability of Rs, and Rn. and P(Rs) is the prior probability of Rs. Since P(Rs) is constant over non shadow region so (1) can described as

$$Rn'=\arg\max P(Rn,Rs) \qquad (3)$$

II.METHODOLOGY

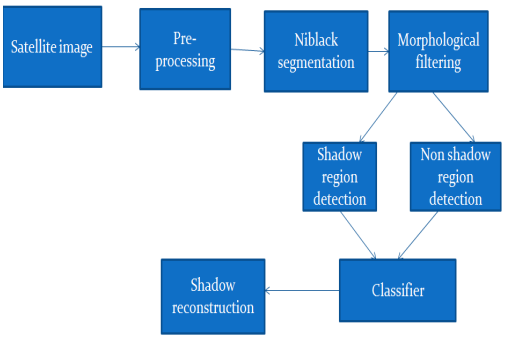


Fig 1.Block Diagram of Proposed Method

Figure 1 shows the block diagram of proposed method. The procedure consists of shadow detection and reconstruction. Shadow detection is done by thresholding, morphological filtering. The input image is a multi-spectral satellite image which has the ability to extract information which the human eye fails to capture. In reconstruction phase shadow and non-shadow pixels are manually separated from the study scene and a shadow and non- shadow library formed.After that, these pixels are correlated by using Markov Random field(MRF).Then non shadow pixel reconstructed from the shadow pixel by Naive Bayes classifier along with the mask derived at the filtering stage.

III COMPARISON OF SEGMENTATION METHODS

Three types of segmentation methods are compared. Which include Otsu's method,Sauvola based segmentation and Niblack Segmentation.

A.Sauvola Based Segmentation

This algorithm perform local thresholding on two dimensional array images. For this purpose the input image must be gray scale .First input image is converted to gray scale image by classical luminance equation.

$$\text{Luminance} = 0.299R+0.587G+0.114B \qquad (4)$$

Then algorithm performs on gray scale images.It determines the threshold value of each pixel by calculating the mean(m) ,standard deviation(S) and dynamic range of gray level value(R).Threshold value can be calculated by the following formula

$$T_{sauvola}=m*(1-k*(1-\tfrac{S}{R})) \qquad (5)$$

In this metod,window of size'w' is centered around each pixel and then calculate the values of mean, standard deviation and dynamic range.But the disadvantage is that, it added a large amount of noises.

B.Otsu's Method

In this method the threshold level can be determined by the bimodal histogram splitting method [15]. The threshold level T is set to the mean of the two peaks in the NIR histogram which was found by experiments to give consistently accurate threshold levels in separating the shadow from the non shadow regions. It performed on NIR band because shadow regions are easily visible. The shadow mask is then derived by the following formula

$$M_T = \begin{cases} 1, & if \quad DN_{NIR} > T \\ 0, & else \end{cases} \qquad (6)$$

Were M_T is the threshold vale and DN_{NIR} is the digital number of NIR band.The disadvantage of this method is detection of wrong shadow regions are very high.

C.Niblack Segmentation

It is a type of local thresholding method [22].Threshold value is calculated by finding the local mean and standard deviation and the value is derived by the equation,

$$T_{niblack}=m+k*s \qquad (7)$$

where m,k and s are the mean ,offset and standard deviation, respectively. The size of neighbourhood should be small enough to preserve the local details and large enough to supress the noise.

$$T_{niblack}=m+k\sqrt{\frac{1}{NP}\sum(P_i-m)}\text{^}2 \quad (8)$$

$$=m+k\sqrt{\sum\frac{1}{NP}(P_i^2-2P_i+m^2)} \quad (9)$$

$$=m+k\sqrt{B} \quad (10)$$

A window of size w is placed around the centre of a current pixel. The window size determines the mean and standard deviation .Niblack algorithm suggest the value of k as -0.2.In Sauvola based segmentation it performs local thresholding of 2D array images.By calculating the mean .After comparing various type of segmentation techniques like Sauvola algorithm and Otsu's method With Niblack segmentation, the better result was observed by using Niblack method. An example of a shadow mask derived from the three thresholding methods are shown in Fig. 2 (a),(b),(c) and (d) with black indicating shadow pixels and white indicating nonshadow pixels.

a)

b)

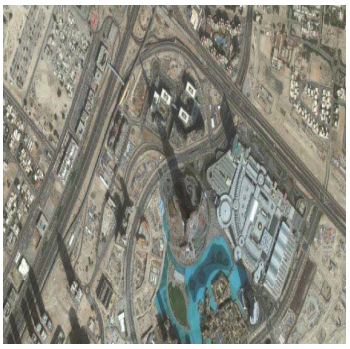
c)

d)

Fig 2.a)Original image b) Segmented image by Sauvola method c)segmented image by Otsu's method d) segmented image by Niblack method

IV.MORPHOLOGICAL FILTERING

Morphological filtering is used to remove the wrong shadow regions for better detection of shadow region. The basic morphological operators are erosion, dilation, opening and closing. Erosion will shrink the image from its original shape. [8]The structuring element move from top to bottom and left to right and in each shift process look for any similar pixel overlapped [2].If there is any overlap then the pixel under the centre of structuring element turns to black. Dilation operation will enlarge the image from its original shape. Like erosion the in each shift process look for complete overlapping of any similar pixel. If there is no complete overlapping then all pixel turned to white. By combing erosion and dilation operation two new operation is formed that is opening and closing. Opening removes small protrusions and thin connections and closing removes small holes. To remove the effect of penumbra one pixel must be [1]compensated at the edge. For this both shadow area and surrounding higher brightness area is grown towards to-light and back-light direction by dilation operation. And the intersecting region is shadow edge compensated region.



a)

b)

c)

d)

Fig 3.a) Original image b) Output after Morphological open c) morphological close.d) after edge compensation

V.SHADOW RECONSTRUCTION

To recover the non-shadow pixels from the corresponding shadow region, Markov random field(MRF) is used to generate a depth based segmentation [10]. pixels in the image have Markov property. Markov property means future states depend on present state not on the past. In other words each pixel in the Markov network are statistically independent. This image is compared with the shadow mask generated through Niblack process[11].From the segmentation method shadow and non shadow regions are separated.For Each shadow region, surrounding non shadow regions are labelled .These neighbours are defined by their minimum distances with the pixel of interest. So the absolute difference is manipulated for every shadow pixel with other non-shadow pixels in the image. Four non shadow regiones in the nearest neighbourhood (i.e., having minimum distances) are selected and grouped. From these neighbourhood non shadow regions, Niave Beyesian classifier predicts the intensity and contrast value of the shadow region.Naive Bayesian classifier is used for solving the Markovian random field. Both MRF and Bayesian are complimenting to each other.The unknown shadow pixel in the scene of interest is taken as the hypothesis 'H'. The well-defined non shadow pixels are referred to as Evidence 'E'. The non-shadow pixel in the nearest neighborhood referred as $E \cap H$.This paper perform 2 type of computation ie, prior probability and posterior probability.ie,probability of H before E is observed(prior probability) and probability of H after E is observed(posterior probability).Consistency of E with observed hypothesis is given as,

$$P(E|H) = \frac{P(E \cap H)}{P(H)} \qquad (11)$$

The formulation for the posteriori probability P(H|E) is given by

$$P(H|E) = \frac{P(E|H).P(H)}{P(E)} \qquad (12)$$

The Hypothesis H i.e., the detected shadow pixel of interest is updated with this posteriori value P(H|E). With this the uncertainty is concluded.

VI. RESULT AND DISCUSSION

In this section a Multi spectral(MS) satellite imagery is taken to evaluate the performance of the methodology. Figure 4(a) shows the shadow mask by thresholding. From which almost all shadow areas are detected. However there is many small regions and wrong shadow region are present due to the presence of wrong shadow region and low DN value. To remove this morphological filtering operation is applied. Figure 4(b) shows the result of morphological opening. To remove small holes closing operation is applied. Figure 4(c) shows the result of closing.. Due to the presence of penumbra detection is very much difficult so to remove this edge compensation is applied. Figure 4(d) shows the result of edge compensation.

Then shadow and non-shadow pixels are separated from the whole scene and a shadow library and non-shadow library is formed. Naïve Beyesian classifier predicts the intensity and contrast value of the shadow region.Bayesian classifier is used for solving the Markov random field.. Figure 4(e)Shows the result after applying Markov random field Figure 4(f) shows the result after reconstructing image.

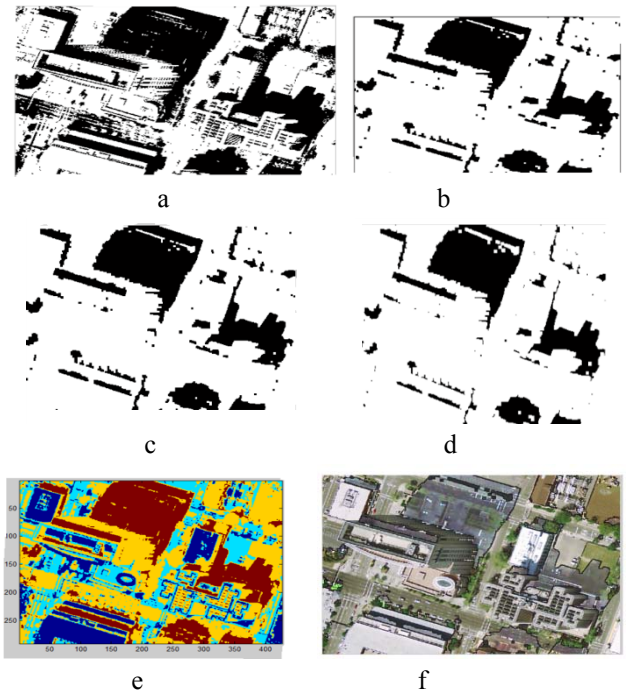


Figure 4. (a) Shadow mask by thresholding (b) shadow region obtained by morphological filtering (c) shadow region obtained by edge compensation (e)Segmentation using MRF (f) Reconstructed image.

To demonstrate the quality of this method Performance analysis is performed. Accuracy and precision of this method is given by the equations

$$A(\text{Accuracy}) = (TP+TN)/(TP+TN+FP+FN) \quad (13)$$

$$TPR = TP/(TP+FN) \quad (14)$$

$$TNR = TN/(TN+FP) \quad (15)$$

$$P = TP/(FP+TN) \quad (16)$$

Table 2.Performance Analysis

Methods	TPR	TNR	Accuracy	Precision
Sauvola method	0.835	0.629	0.802	0.993
Otsu method	0.802	0.613	0.820	0.991
Niblack method	0.938	0.629	0.941	0.989

True positive rate(TPR) measures the proportion of positives that are correctly identified as such and True negative rate (TNR) measures the proportion of negatives that are correctly identified as such.

After performance analysis it is found that accuracy of this method is 94% it is obtained by taking average of the accuracies obtained with various images.

VII. CONCLUSION

A novel shadow detection and reconstruction algorithm which deals with high resolution satellite imagery is proposed here..Niblack segmentation and filtering operations are used to detect the shadow areas. To reconstruct the shadow pixel a shadow reconstruction algorithm is developed. This algorithm is based on Bayes classifier and using MRF which considers the associativity between the reconstructed shadow region and their corresponding non shadow region. MRF will determines the information and Bayesian classifier will solve the uncertainty based on the observations using probabilistic theorems. After comparing various type of segmentation algorithms like Sauvola and Otsus's method with Niblack. Niblack provide better reconstructed result with naïve Bayes classifier with the accuracy of 94%.

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