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"Object Shadow Detection and Removal from Remote Sensing Images using Successive Thresholding Method"

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***Abstract*—** Now a day's capturing a live images with high quality plays an crucial role in all the fields. It is more important as far as security in military, commercial, household fields as well as to monitor the continuous changes in earth surfaces are concern. Most of the time to achieve clear images we have to differentiate between original object and shadow as detecting objects under the influence of shadow is a challenging task. In urban area the shadow produces artificial color features and shape deformation of objects which decays the quality of image. Shadow mainly occurs due to elevate objects and If light source has been blocked by some obstacles. However, a lot of shadowed areas in remote sensing images of urban areas have affected the tasks, such as image classification, object detection and recognition. Tsai presented an efficient algorithm which uses the ratio value of the hue over the intensity to construct the ratio map for detecting shadows of color aerial images. Instead of only using the global thresholding process in Tsai's algorithm, this paper presents a novel successive thresholding scheme (STS) to detect shadows more accurately. By performing the global thresholding process on the modified ratio map, a coarse-shadow map is constructed to classify the input color aerial image into the shadow pixels and the non-shadow pixels. Instead of only using the global thresholding process in Tsai's algorithm, this paper presents a novel successive thresholding scheme (STS) to detect shadows more accurately. For the three four testing images, which contain some low brightness objects, our proposed algorithm has better shadow detection accuracy when compared with the previous shadow detection algorithms proposed by Tsai. Thus for the correct image interpretation it is important to detect shadow regions and restore their information. So it is very essential to detect the shadow regions and remove it effectively to get useful information with good quality.

Keywords: Shadow detection method, Successive Thresholding Algorithm, Shadow removal, Otsu's method, Image Segmentation, Tsai's algorithm, Adaptive Histogram Equalization and Image Adjustment.

I. INTRODUCTION

SHADOWING is one of the main and inevitable acquisition artifacts in high-resolution, urban aerial, very high resolution satellite and optical images. In urban aerial images, shadows usually result in information loss or distortion of objects. In almost all cases, optical satellite images are contaminated with shadow. In order to perform a successsful change detection using time series of images or to use a single image. In VHR optical images, particularly in urban areas, the presence of shadows may completely destroy the information contained in those images. The VHR satellite imageries are capable of providing a high level of detail, which make them a reliable and highly vital source of information. Therefore, the VHR satellite imageries support a range of services, especially in urban areas, for city planning and monitoring, urban change detection, estimation of human activities/population, and urban object/feature detection. If we consider the urban areas then we can easily get that, surfaces are quite complex, shadows formed by elevated objects like some tall buildings, bridges and trees Images are obtained in different areas of the Earth with different conditions of the atmosphere, intensity and the spectral characteristics of the images which have high variations. High-resolution images provided by latest missions such as QuickBird, Ikonos, or OrbView have opened a new range of applications in the remote sensing field because of the possibility of extracting detailed information from the images. The quality of data processing may be significantly degraded by the appearance of shadows in urban areas. A shadow indicates the shape of the object casting it, and in many ways it can indicate the texture of the surface receiving the shadow A shade can be defined as the side of an object which is opposite to the direction of illumination, which has less colour tone of the full blackness (the value intensity of darkness) compared to the objects' shadows that have very low values of brightness in VHR images. The line that locates and separates the light and shade areas on the object determines the shadow line on a receiving surface. Shadows cause difficulty in feature extraction, pattern recognition and image matching of shadow area images, especially for the high-resolution urban aerial images. In one consideration shadows themselves can be useful for the information in 3-D reconstruction, building position, height estimation. However, for color aerial images, the shadow detection accuracy can be improved by utilizing both the intensity and the color information Based on the three features, which are intensity values, geometrical properties, and light directions, several efficient algorithms have been presented to detect shadows for gray aerial images. The task of an automatic shadow detection becomes very complex. Prevention of errors caused by this kind of artifacts is still a current topic. So, the detection and removal of shadows play an important role in applications of urban high-resolution sensing images for object classification and recognition, change detection and image fusion and in area of computer image processing and analysis, and machine vision.

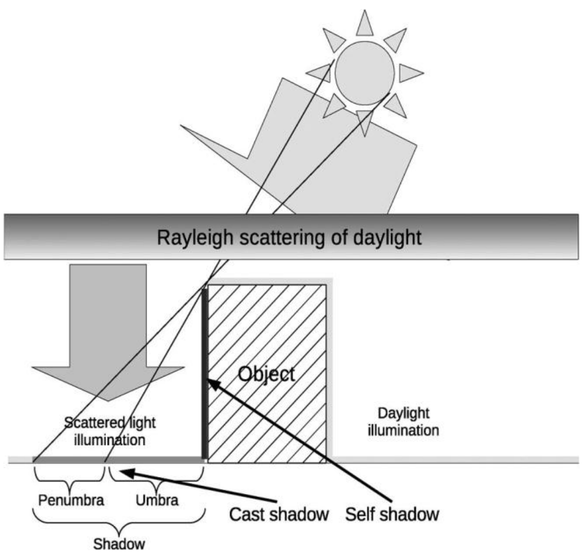

Figure 1. Shadow area formation.

A Shadow is created when an object lies in the path of a light source. Shadows are cast by the occluding object, or the object itself can be shaded; a phenomenon known as "self-shading". Due to the difference between the light intensity reaching a shaded region and a directly lit region, shadows are often characterized by strong brightness gradients. While non-shadow regions are illuminated by both direct (e.g., sunlight, flashlight) and diffuse (e.g., skylight, fluorescent, incandescent) light sources, shadow regions are only illuminated by diffuse light. The change between shadow and non-shadow regions is thus not only a brightness difference, but a color one as well. The Illumination of an outdoor area is characterized by two main light components: direct sunlight and the atmospheric. The area under sunlight illumination is characterized by daylight sun illumination spectra, while the shadowed area is characterized primarily by the spectra of the scattered sunlight shown in figure1. The diffusion of sunlight in the atmosphere is caused by Rayleigh and aerosol scatterings. Obscuring objects from the direct sunlight causes the appearance of shadows, and the objects in this area are illuminated by the scattered light.

Normally, shadows appear when objects occlude the direct light from the illumination source, usually the sun. Also Shadows occur when objects totally or partially occlude direct light from a source of illumination. However, shadows are not all the same; they can be divided into two different classes: cast and self shadows (see Fig. 1). Cast shadow is caused by the projection of the light source in the direction of the object. Cast shadows in optical images result form the light source being blocked by objects and therefore, parts of the image are not illuminated by the direct light. These regions are usually among the darkest areas in an image and can be easily misclassified as other dark objects such as water. Self shadow is still a shadow but represents the part of the object that is not illuminated directly by the light source.

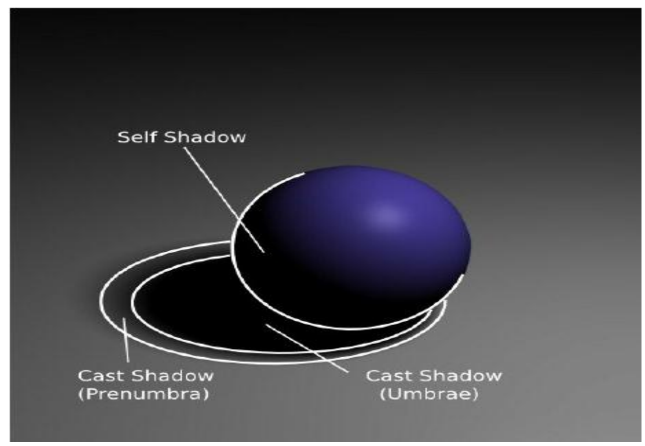

Figure 2. Types of shadows.

As shadows can be divided into two classes: cast and self . A cast shadow is projected by the object in the direction of the light source; a self shadow is the part of the object which is not illuminated by direct light. The part of a cast shadow where direct light is completely blocked by an object is called the umbra, while the part where direct light is partially blocked is called the penumbra as shown in figure 2. The shadow is divided into two classes of projected shadow and self-shadow. The shadow of image provides direct evidence for existing of large objects. The shadow is used to targets recognition such as building positioning, height estimation, slope calculation. So this paper focuses on detection and removal of shadow from remote sensing images by using Tsai's algorithm and successive thresholding algorithm. For this purpose we have concentrated on system history, System design, new analysis based/ successive thresholding algorithm, shadow removal algorithm and results-discussion with conclusion section.

II. SYSTEM HISTORY

As shadow are natural phenomenon, which occur when the light is blocked by particular light sources. Although the shadow provide important visual cues for object shape perception, illumination position, objects occlusion. The shadow free images can help to improve the performance of the tasks such as object recognition, object tracking and information enhancement. For this the shadow detection and removal is a popular research direction in computer vision and image processing communities. Many effective algorithm have been proposed for shadow detection. Existing shadow detection methods can be roughly categorized into two groups: model-based methods and shadow feature based methods. The first group uses prior information such as scene, moving targets and camera altitude to construct shadow models. This group of methods is often used in some specific scene conditions such as aerial image analysis and video monitoring. The second group of methods identifies shadow areas with information such as gray scale, brightness, saturation and texture, An improved algorithm edists that combines the two methods. First, the shadow areas are estimated according to the space coordinates of buildings calculated from digital surface models and the altitude and azimuth of the sun. Then, to accurately identify a shadow, the threshold value is obtained from the estimated gray-scale value of the shadow areas. The past shadow detection work by Tsai's algorithm as given below:

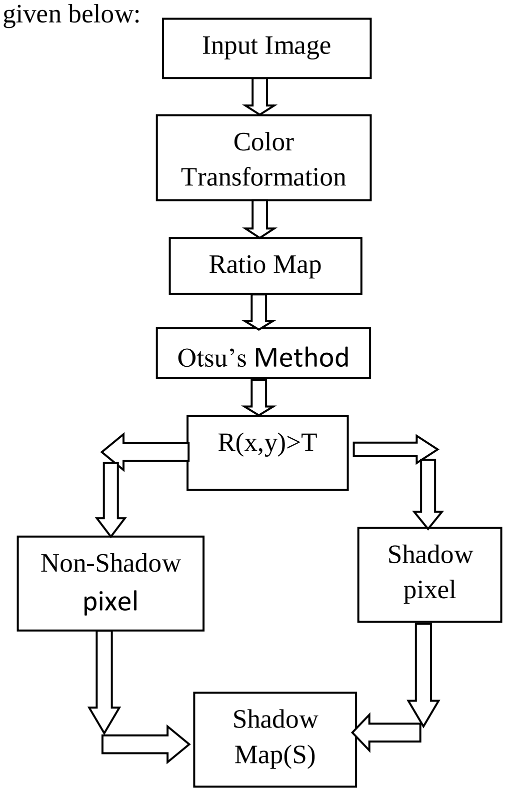

Figure 3. Flowchart of shadow detection algorithm.

Shadow detection uses Tsai's algorithm with successive steps such as color transformation of captured image, calculation of Ratio map, Otsu's method, and last step is nothing but obtaining shadow map by differentiation between shadowed and non-shadowed pixel.

I.INPUT IMAGE- The shadow detection flowchart takes satellite or drone captured high resolution color image as a input image. An image, digital image, or still image is a binary representation of visual information, such as drawings, pictures, graphs, logos, or individual video frames. Digital images can be saved electronically on any storage device. An image is a picture that has been created or copied and stored in electronic form. An image can be described in terms of vector graphics or raster graphics. An image stored in raster form is sometimes called a bitmap. An image map is a file containing information that associates different locations on a specified image with hypertext links. Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. There are many type of images such as binary image, Black and white image**.** The common image file formats are JPEG, GIF, PNG, SVG, TIFF, PPM, BMP, XWD.

II.COLOR TRANSFORMATION- The input image has to transformed into the particular color models like hue, saturation, and intensity (HSI);hue, saturation, and value (HSV);hue, chroma, and value (HCV); or luminance, hue, and saturation (YIQ); luma, blue-difference chroma, and red-difference chroma (YC_bC_r). Among these invariant color models, Tsai's algorithm has the best shadow detection performance for the *HSI* model.This paper only focuses on HSI color model so that by using two shadow properties, the red, green, and blue (RGB) color aerial image is first transformed into the hue, saturation, and intensity (HSI). Conversion between the RGB model and HSI model is quite complicated. The Hue component describes the color itself in the form of an angle between [0,360] degrees. 0 degree mean red, 120 means green 240 means blue. 60 degrees is yellow, 300 degrees is magenta. The Saturation component signals how much the color is polluted with white color. The range of the S component is [0,1].The Intensity range is between [0,1] and 0 means black, 1 means white.

III.RATIO MAP- In the HSI model, H and I componentsare called as intensity and hue-equivalent components. By scaling H and I components in the range between [0,1]. We can obtain the intensity-equivalent image I_e and hue-equivalent image H_e, respectively. The ratio map R is given by

$$R(x,y) = \frac{H_e(x,y)+1}{I_e(x,y)+1}$$

(1)

Where R (x, y), H_e (x, y) and I_e (x, y) denote the pixel at position (x, y) of R, the image H_e, and the image I_e, respectively. In Tsai's (algorithm) method, the value of R (x, y) is scaled to the range [0, 255] for shadow detection.

IV.OTSU'S METHOD- In the year 1979, Otsu proposed the highest class variance method (known as the Otsu method). For the easy computation, constancy & effectiveness, this method has been extensively used. It is a well-performed mechanical threshold selection process, & the time it consumes is considerably less than the other thresholding algorithms. Otsu's thresholding method entails iterating through all the probable threshold values & computing a gauge of spread for all the pixel levels at each side of the threshold, i.e. the pixels which either fall in the foreground or background. The main objective is to calculate the threshold value at places where the addition of foreground & background spreads is at its least possible value. The algorithm will be revealed using the simple 6x6 image exposed below. The histogram for the image is also given away subsequently to it. To make simpler the description, only 6 grayscale levels are used. In computer vision and image processing, Normally Otsu's method is used for the reduction of a gray level image to a binary image. Otsu's method is one of binarization algorithm which is invented by Nobuyuki Otsu. In the computer vision & image processing, Otsu's method' is used to mechanically execute histogram shape-based image thresholding, or, the decrease of a gray level image to a binary image. The algorithm take for granted that the image to be thresholded consists two groups of pixels or bi-modal histogram (for instance, foreground & background) and then evaluates the optimum threshold partitioning those two classes so that their joint spread (intra-class variance) is negligible. The expansion of the basic method to multi-level thresholding is addressed to as the Multi Otsu method. Otsu's method is named so after the Nobuyuki Otsu Method.

V.SHADOW MAP- The Otsu's thresholding method is applied on ratio map R to determine the threshold T which can be used for separating all the pixels of R into two classes. Based on threshold T, a shadow map S can be obtained as given below

$$S(x,y)=\begin{cases}1, & R(x,y)>T\\ 0, & Otherwise\end{cases} \quad (2)$$

Where $S(x,y) = 1$ denotes the shadow pixel at position (x,y) and $S(x,y) = 0$ denotes the non shadow pixel at position (x,y).

III. SYSTEM DESIGN

As the Shadow detection and removal from the images has been a crucial aspect in all the field so that the vital information about structural features of object can be preserved. This paper uses following block diagram which consists of image segmentation, Suspected shadow detection, Elimination of false shadow, exact shadow removal from images using image enhancement method with adaptive histogram equalization and image recovering the original image without incurring losses. Original image is a drone or satellite captured high resolution color image which consists of a shadow. Image segmentation is an important step in image understanding and computer vision system. Image segmentation is a process of dividing the entire digital image into several segments to identify the location of objects and boundaries (line.curves). Image segmentation is a set of contour extracted from the digital image. This can be achieved by applying different methods like thresholding method, edge

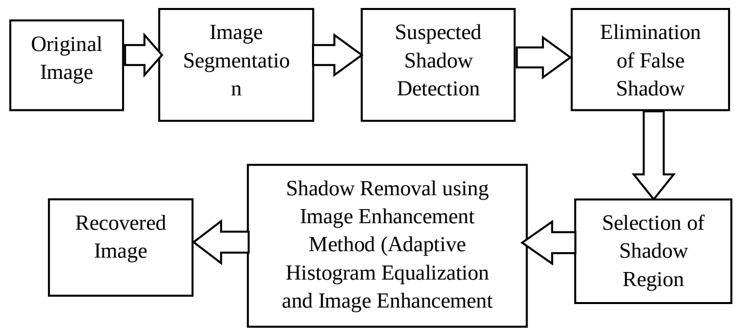

Figure 4. Block diagram of system design.

based method, Region based method Clustering method, watershed method, PDE based method, ANN based method. This paper uses thresholding method for image segmentation. Thresholding method is a simple method of image segmentation and works very well for finding the threshold after application of suitable histogram. This method takes gray scale or color image as a input and produces binary image as a output image. This method replaces each pixel in an image with a black pixel if the image intensity $I_{i,j}$is less than some fixed constant T (that is $I_{i,j} < T$), or a white pixel if the image intensity is greater than that constant.The Black pixels correspond to background and white pixels correspond to foreground. Single value thresholding can be given mathematically as follows: For color or multi-spectral images it may be possible to set different thresholds for each color channel, and so select just those pixels within a specified cuboid in RGB space.

IV. NEW ANALYSIS BASED/ SUCCESSIVE THRESHOLDING ALGORITHM

This algorithm uses successive steps like Input Image, Image Transformation, Global thresholding, Morphology Erosion, Convolution Filtering, and Coarse Shadow Map. First three steps of successive thresholding algorithm are exactly same as that of Tsai's algorithm.

I.INPUT IMAGE- In photography and computing, a gray scale digital image is an image in which the value of each pixel is a single sample and it carries only intensity information. This image is also defined as black and white image which constitutes all shades of gray with black at the weakest intensity to white at the strongest.

II.IMAGE TRANSFORMATION- we have to convert an color image into a gray scale image. If each color pixel is constituted by a triple (R, G, B) of intensities for red, green and blue. There are three methods to convert it as given below Lightness method, Average method, weighted Method or luminosity method.

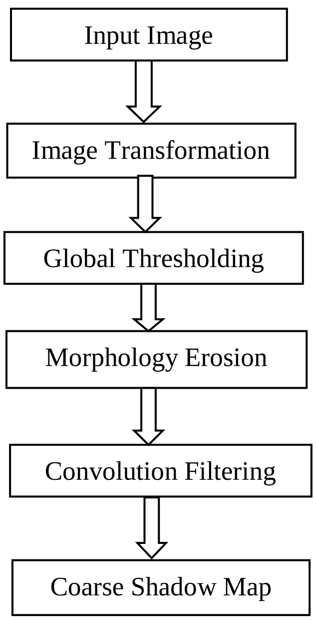

Figure 5. Flowchart of New Analysis Based/ Successive Thresholding algorithm.

1. **Lightness method**-In this method we have to calculate averages the most prominent and least prominent colors by applying following formulae $\frac{(max(R,G,B)+min(R,G,B))}{2}$. (3)
   Lightness method tends to reduce contrast.
2. **Average method-**Average method is a simple method in which we have to calculate the average of three colors by using formulae as given below

$$Gray\ scale\ image = \frac{R+G+B}{3} \quad (4)$$

3. **Weighted method or luminosity method-**red color has more wavelengths of all the three colors, and green is the color that has not only less wavelength then red color but also green is the color that gives more smoothing effect to the eyes. In this method we have to decrease the contribution of red color, and increase the contribution of the green color, and put blue color contribution in between these two. According to this equation, Red has contribute 30%, Green has contributed 59% which is greater in all three colors and Blue has contributed 11%.

$$\text{Gray scale image} = (0.3 * R) + (0.59 * G) + (0.11 * B). \quad (5)$$

III.Global threshoding- Global thresholding is based on the assumption that the image has a bimodal histogram and, therefore, the object can be extracted from the background by a simple operation that compares image values with a threshold value *T* [32, 132]. Global thresholding is computationally simple and fast. It works well on images that contain objects with uniform intensity values on a contrasting background. However, it fails if there is a low contrast between the object and the background, if the image is noisy, or if the background intensity varies significantly across the image.

The basic global threshold, T is calculated as follows:

$$g(x,y) = \begin{cases} 1 \ if \ f(x,y) > T \\ 0 \ if \ f(x,y) \le T \end{cases} . \quad (6)$$

- Select an initial estimate for T (typically the average grey level in the image).
- Segment the image using T to produce two groups of pixels: G_1 consisting of pixels with grey levels >T and G_2 consisting pixels with grey levels ≤ T.
- Compute the average grey levels of pixels in G_1 to give μ_1 and G_2 to give μ_2
- Compute a new threshold value:

$$T = \frac{\mu_1 + \mu_2}{2} \quad (7)$$

- Repeat steps 2 – 4 until the difference in T in successive iterations is less than a predefined limit T_∞.

IV. MORPHOLOGY EROSION- *Morphology* is a broad set of image processing operations that process images based on shapes. Morphological operations apply a structuring element to an input image, creating an output image of the same size. In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. Morphological image processing pursues the goals of removing these imperfections by accounting for the form and structure of the image. These techniques can be extended to grey scale images. Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image. The structuring element is a small binary image, i.e. a small matrix of pixels, each with a value of zero or one. The matrix dimensions specify the *size* of the structuring element. The pattern of ones and zeros specifies the *shape* of the structuring element, An *origin* of the structuring element is usually one of its pixels, although generally the origin can be outside the structuring element. The most basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the *structuring element* used to process the image. In the morphological dilation and erosion operations, the state of any given pixel in the output image is determined by applying a rule to the corresponding pixel and its neighbors in the input image. The rule used to process the pixels defines the operation as a dilation or an erosion.

(A) DILATION: The value of the output pixel is the *maximum* value of all pixels in the neighborhood. In a binary image, a pixel is set to 1 if any of the neighboring pixels have the value 1. Morphological dilation makes objects more visible and fills in small holes in objects.

(B) EROSION: The value of the output pixel is the *minimum* value of all pixels in the neighborhood. In a binary image, a pixel is set to 0 if any of the neighboring pixels have the value 0.Morphological erosion removes islands and small objects so that only substantive objects remain.

V.FILTERING-Image Filtering is a method for modifying or enhancing an image. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. A processed image is generated as the center of the filter visits each pixel in the input image. If the operation performed on the image pixels is linear then it is referred as a linear spatial filter else it is non-linear.

(A) Correlation Filtering- It is defined as a process of moving a filter mask over the image and computing the sum of products at each location. In correlation, the value of an output pixel is also computed as a weighted sum of neighboring pixels and *correlation kernel*, is not rotated during the computation.

(B) Convolution filtering- Linear filtering of an image is accomplished through an operation called *convolution*. Convolution is a neighborhood operation in which each output pixel is the weighted sum of neighboring input pixels. The matrix of weights is called the *convolution kernel*, also known as the *filter*. A convolution kernel is a correlation kernel that has been rotated 180 degrees. Convolution matrix, or mask is a small matrix useful for blurring, sharpening, embossing, edge-detection. The convolution of f and g is written∗, using an asterisk or star. It is defined as the integral of the product of the two functions after one is reversed and shifted. it is a particular kind of integral transform:

$$(f * g)(t) = \int_{-\infty}^{\infty} f(\tau) g(t-\tau)\, d\tau = \int_{-\infty}^{\infty} f(t-\tau) g(\tau)\, d\tau. \quad (8)$$

In order to perform convolution on an image, following steps should be taken.

- Flip the mask (horizontally and vertically) only once
- Slide the mask onto the image.
- Multiply the corresponding elements and then add them
- Repeat this procedure until all values of the image has been calculated.

V.SHADOW MAP- The calculation of shadow map is same as that of Tsai's algorithm.

V. SHADOW REMOVAL ALGORITHM

Shadow removal algorithm is as shown in figure below and it has various steps such as Shadow map and Input Image, Selection of Shadow Region, Only Shadow Image, Enhance Contrast Using Adaptive Histogram Equalization and Image Adjustment, Patch In painting, Enhanced Shadow Image.

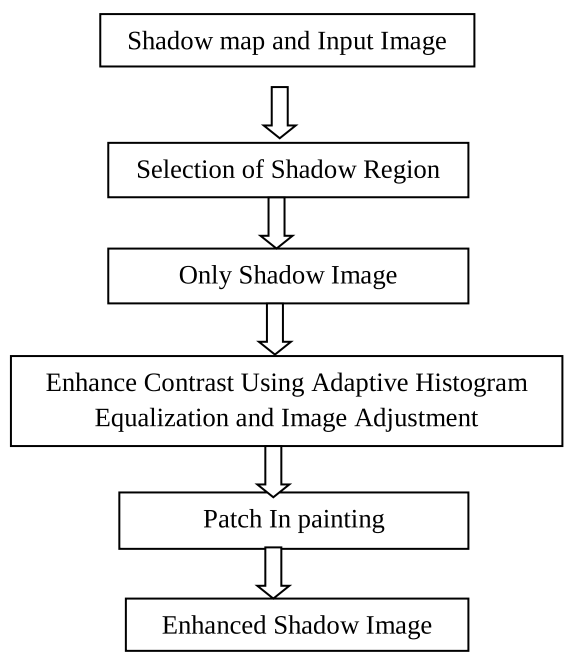

Figure 6. Flowchart of shadow removal algorithm.

Shadow map is obtained from the shadow detection algorithm and input image is a satellite or drone captured high resolution image. Next step is to select the shadowed region from the input image to get only shadow image. The important step to apply adaptive histogram equalization and image adjustment on only shadow image to enhance the contrast of image. Last step is to apply patch in painting to get enhanced shadow image.

(A) Histogram Equalization-Histogram equalization is a technique to adjust image intensities to enhance the contrast. Consider for a moment continuous intensity values and let the variables r denote the intensities of an image to be processed. We assume that r is the range [0,L-1],with r=0 representing black and r=L-1 representing white. For r satisfying these conditions,we have to consider the transformation of the form

$$S=T(r) \qquad 0\leq r \leq L-1. \tag{9}$$

That produce an output intensity level s for every pixel in the input image having intensity r. We have to consider three conditions

- T(r) is a monotonically increasing function in the interval $0\leq r \leq L-1$ and $0\leq T(r) \leq L-1$ for $0\leq r \leq L-1$
- .In some cases we will consider r = T^{-1} (s) $0\leq s \leq L-1$
- T(r) is a strictly monotonically increasing function in the interval $0\leq r \leq L-1$.

For histogram equalization HSI color model is suitable in which only intensity component is equalized. Histogram stretching can be used to increase contrast and histogram equalization is used to enhance the contrast of the captured image by calculating the PDF (probability distribution function) and CDF (cumulative distribution function).

Conventional histogram equalization algorithm is available but it produces some information loss after application. So remedy to avoid this problem to use adaptive histogram equalization algorithm. It adjusts gray levels of an input image according to the PDF of the image and to improve the visual effects of the image it enlarges the dynamic range of of gray level distribution. The histogram equalization algorithm has two types mainly local histogram equalization and global histogram equalization. The global histogram equalization algorithm has advantages in concern of processing speed and has problem in enhancing effects.

Adaptive histogram equalization has various method such as contrast limiting adaptive histogram equalization or CLAHE, multi peak histogram equalization (MPHE), and multipurpose beta optimized bi-histogram equalization (MBOBHE).

(B) Analysis of Histogram Equalization algorithm:
Suppose the gray value of the pixel in the original image is r (0≤r≤1) and its probability density is p(r), the gray value of the pixel in the enhanced image is s (0≤s≤1) and its probability density is p(s), and the mapping function is s=T(r).

$$P_s(s)ds = P_r(r)dr \tag{10}$$

Suppose s=T(r) is a monotonically increasing function in the interval and its inverse function r = $T^{-1}(s)$ is a monotonic function. So we can write

$$P_s(s) = [p_r(r)\frac{1}{ds/dr}]_{r = T^{-1}(s)} = P_r(r)\frac{1}{Pr(r)}= 1 \tag{11}$$

The mapping relationship of the conventional histogram equalization algorithm: In discrete conditions, the relationship between i (the gray value of the pixel in the original image) and f_i (the gray value of the pixel in enhanced the image) is

$$F_i = (m-1)T(r) = (m-1)\sum_{k=0}^{i}\frac{qk}{Q}. \tag{12}$$

where, m is the number of gray levels presented in the original image, qk is the number of pixels in the image with k th gray level, Q is the total number of pixels in the image. Suppose an image has n different gray levels, and the occurrence probability of i th gray level is pi , so the entropy of the gray level may be defined as

$$e(i) = -p_i \log p_i. \tag{13}$$

The entropy of the whole image is

$$E = \sum_{i=0}^{n-1} e(i) = -\sum_{i=0}^{n-1} pi \log pi. \tag{14}$$

E will achieve its maximum if and only if $P_0 = p_{12} = . . . = P_{n-1} = \frac{1}{n}$.

That is to say the entropy of the whole image achieves its maximum when the histogram of the image has uniform distribution. From F_i equation, it is clear that the dynamic range has been enlarged after equalization. The essence of the equalization is to expand the quantization interval.

(C) Patch in Painting- Patch in painting is the process of reconstructing lost or deteriorated parts of images and videos. In the digital world, in painting (also known as image interpolation or video interpolation) refers to the application of sophisticated algorithms to replace lost or corrupted parts of the image data. This technique can be used to replace the lost blocks in the coding and transmission of images, for example, in a streaming video. It can also be used to remove logos in videos and also used for film restoration in photography. In painting is rooted in the restoration of images and this methodology uses steps as follow:

- The global picture determines how to fill in the gap. The purpose of in painting is to restore the unity of the work.

- The structure of the gap surroundings is supposed to be continued into the gap. Contour lines that arrive at the gap boundary are prolonged into the gap.
- The different regions inside a gap, as defined by the contour lines, are filled with colors matching for those of its boundary.
- The small details are painted, i.e. “texture” is added.

It has various types of inpainting like Structural inpainting, Textural inpainting, Combined structural and textural inpainting.

(D) Enhanced shadow region- After performing sequenmtial steps of Selection of Shadow Region, application of Enhance Contrast Using Adaptive Histogram Equalization and Image Adjustment and patch in painting we are getting enhanced shadow region.

VI. RESULTS AND DISCUSSION

In this paper, some experimental results are demonstrated to show the shadow detection accuracy comparison between Tsai’s algorithm and our new analysis algorithm along with shadow removal using our new analysis algorithm. Both algorithm for shadow detection and removal is executed using MATLAB R2012, all image were tested on Intel Core i5,4GB RAM using MATLAB R2012a.Output image result were obtained in approximately 10 to 12 seconds.

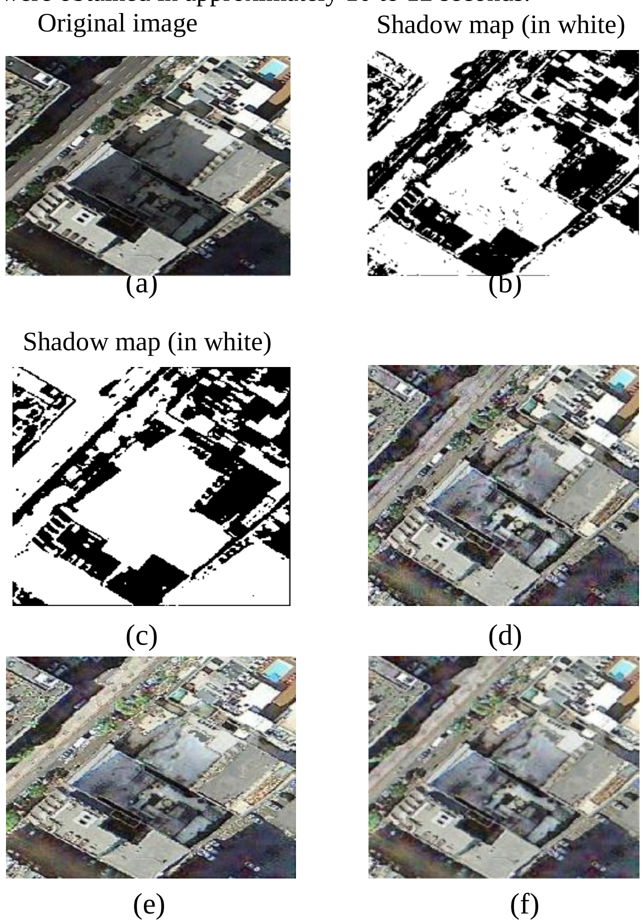

Figure 7 -(a) Original image.(b) Shadow detection by Tsai’s algorithm.(c) Shadow detection by our new analysis based algorithm.(d) shadow removal (Enhanced shadow image) using adaptive histogram equalization.(e) shadow removal (Enhanced shadow image) using image adjustment.(f) final shadow removal for image.

In Figure 7-(a) Show original image. Shadow detection by tsai’s algorithm shown in Figure 4.7 (b).In that white portion nothing but shadow regions and dark portion is non shadow regions. Shadow detection by our new analysis based algorithm shown in Figure 4.7 (c).In which white portion is shadow regions and dark portion is non shadow regions. Image enhancement using adaptive histogram equalization and image adjustment shown in Figure 4.7(d),4.7(e),respectively. Final shadow removal for original image (a) shown in Figure 4.7(f).

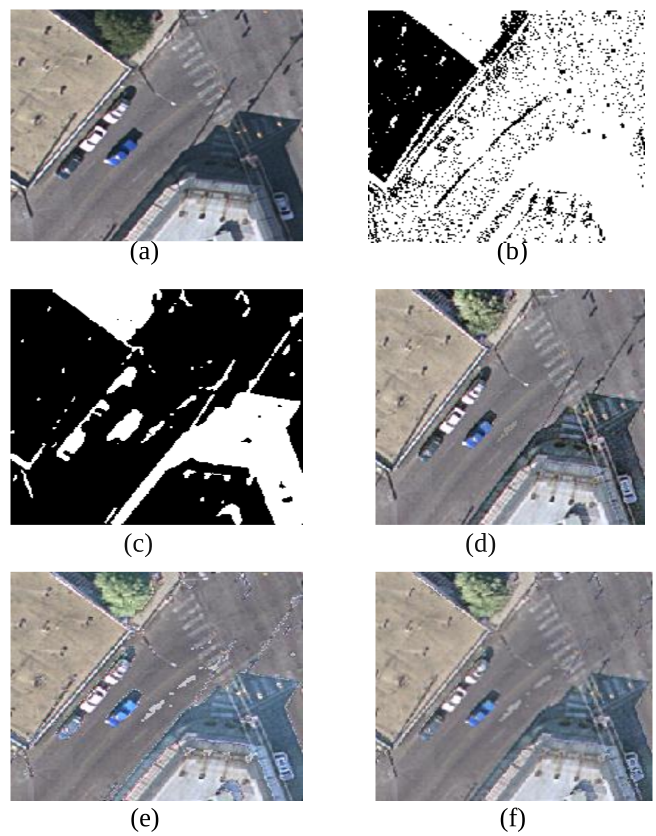

Figure 8-(a) Original image.(b) Shadow detection by Tsai’s algorithm. (c) Shadow detection by our new analysis based algorithm.(d) shadow removal(Enhanced shadow image) using adaptive histogram equalization.(e) shadow removal(Enhanced shadow image) using image adjustment.(f) final shadow removal for image(a).

SUBJECTIVE EVALUATION:

Figure 4.9(a)-4.10(a) show the four testing images, and the corresponding manually interpreted shadow maps, which are used as the ideal shadow maps to evaluate the shadow detection performance, are shown in Figure4.9(b)–4.10(b), respectively. The shadow detection results of the algorithm of Tsai's algorithm and our proposed algorithm are demonstrated in Figure. 4.9 (c)–4.10 (c) and Figure. 4.9(d)–4.10(d), respectively.

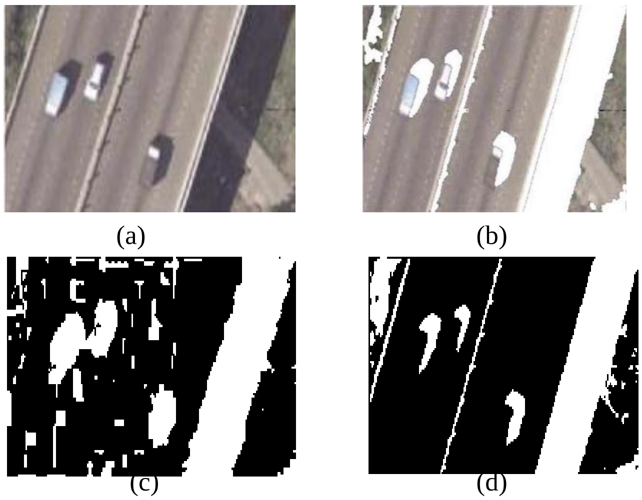

Figure 9-(a) Original image. (b) Ideal shadow map. (c) Shadow detection using Tsai's algorithm. (d)Shadow detection using our based algorithm.

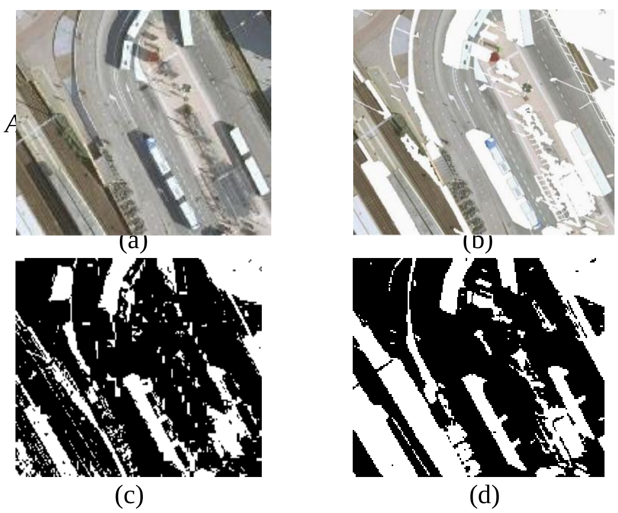

Figure 10-(a) original image. (b) ideal shadow map. (c) shadow detection using tsai's algorithm. (d)shadow detection using our based algorithm.

In five testing images as shown in Figure 4.9(a)-4.10(a), it is observed that our proposed algorithm has the best accuracy performance than Tsai's algorithm and the detection results by our proposed algorithm are close to the ideal shadows marked in Figure 4.9(b)-4.10(b), respectively.

OBJECTIVE EVALUATION:

In this section, three types of accuracy, namely the producer's accuracy, the user's accuracy, and the overall accuracy for Tsai's and our algorithm are used in the objective evaluation. The three types of accuracy are described as follows.

The first type of accuracy is the **producer's accuracy**, which contains two parameters $\eta s$and $\eta n,$ and they are defined by

$$\eta s = \frac{TP}{TP + FN} \qquad \eta n = \frac{TN}{FP + TN} \tag{15}$$

where true positive (TP) denotes the number of true shadow pixels which are identified correctly; false negative (FN) denotes the number of true shadow pixels which are identified as nonshadow pixels; false positive (FP) denotes the number of nonshadow pixels which are identified as true shadow pixels; and true negative (TN) is the number of nonshadow pixels which are identified correctly.

The parameter ηs (ηn) denotes the ratio of the number of correctly detected true shadow (nonshadow) pixels over that of total true shadow (nonshadow) pixels. The second type of accuracy is the **user's accuracy** in terms of$ps$and $pn,$ which are defined as

$$ps = \frac{TP}{TP + FP} \qquad pn = \frac{TN}{TN + FN} \tag{16}$$

The parameter ps (pn) denotes the ratio of the number of correctly detected true shadow (nonshadow) pixels over that of the total detected true shadow (nonshadow) pixels, and thus, the user's accuracy can be used to measure the precision of the shadow detection algorithm. Combining the accuracies of the user and the producer, the third type of accuracy **(overall accuracy)** τdefined as follows can be used to evaluate the correctness percentage of the algorithm:

$$\tau = \frac{TP + TN}{TP + TN + FP + FN} \tag{17}$$

where $TP + TN$ denotes the number of correctly detected true shadow and nonshadow pixels; $TP + TN + FP + FN$ is equal to the number of total pixels in the image.

Table 1 Shadow Detection Accuracy Measurements for Figure 4.9 (a)

Method	Producer's accuracies		User's accuracies		Overall accuracies
	ηs(%)	ηn(%)	ps(%)	pn(%)	τ(%)
Proposed	96.15	96.20	96.20	96.15	96.17
Tsai's	94.204	90.86	90.86	94.204	93.19

Table 2 Shadow Detection Accuracy Measurements for Figure 4.10 (a)

Method	Producer's accuracies		User's accuracies		Overall accuracies
	ηs(%)	ηn(%)	ps(%)	pn(%)	τ(%)
Proposed	96.89	84.56	84.56	96.89	91.30
Tsai's	93.44	89.46	89.46	93.44	90.40

Table 3 Average accuracies measurements for figure 4.7-4.10

Method	Overall Accuracies (Table 1)	Overall Accuracies (Table 2)	Average Accuracies
Proposed	96.17	90.30	84.193
Tsai's	93.19	91.40	76.05

From the aforementioned three types of accuracy, Table 4.7-4.10 show the accuracy comparison between Tsai's algorithm and our new algorithm for Figure 4.7(a)-4.10(a), respectively. Table 4.20 shown Average accuracies of our proposed and tsai's algorithm for Table 1-2 shown that accuracy of our new method is better than tsai's algorithm. Hence, According to table 3 overall shadow detection using our new method gives better results than tsai's.

VII. CONCLUSION

We have put forward our new algorithm for shadow detection and removal with successive steps. The captured Images are converted into different invariant colour spaces to obtain shadows. The system history discussed the Tsai's shadow detection algorithm for various images such as Remote sensing images, aerial images, satellite images, Urban high-resolution remote sensing images, Color aerial images, High resolution satellite images, VHR Images. This paper has well defined system design because shadow detection and removal from the images has been a crucial aspect in all the field so that the vital information about structural features of object can be preserved. Our new algorithm calculates three type of accuracy like producer's, user's and overall accuracy for comparing the results of shadow detection and removal. From the results and discussion section we can conclude that the accuracy of shadow detection using our new algorithm is better than Tsai's algorithm. The new analysis based algorithm provides shadow removal results are more correct only when shadow detection properly take place or more accurate.

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