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A Review: Shadow Detection and Removal

Vijay Chondagar
Student of Msc.(IT)
Uka Tarsadia University, Bardoli, Surat,India

Harshiv Pandya
Student of Msc.(IT)
Uka Tarsadia University, Bardoli, Surat, India

Mehul Panchal
Student of Msc.(IT)
Uka Tarsadia University, Bardoli, Surat

Rinkesh Patel
Student of Msc.(IT)
Uka Tarsadia University, Bardoli, Surat

Dhaval Sevak
Student of Msc.(IT)
Uka Tarsadia University, Bardoli, Surat

Kaushal Jani
Teaching Assistant
Uka Tarsadia University, Bardoli, Surat

***Abstract*-- Shadow detection and removal in various real life scenarios including surveillance system, indoor outdoor scenes, and computer vision system remained a challenging task. Shadow detection and removal is a very crucial and inevitable task of some computer vision algorithms for applications such as image segmentation and object detection and tracking. Shadows in an image can reveal information about the object's shape and orientation, and even about the light source. Shadow in traffic surveillance system may misclassify the actual object, reducing the system performance. Researchers have developed numerous algorithms and techniques that help to detect a shadow in image and remove such shadow from that image. This paper is aimed to provide a survey on various algorithms and methods of shadow detection and removal with their advantages and disadvantages. This paper will serve as a quick reference for the researchers working in same field.**

***Keywords*-- Shadow Image Processing, Shadow, Shadow Detection, Shadow Detection and Removal Algorithm.**

I. INTRODUCTION

Image processing has been one area of research that attracts the interest of wide variety of researchers. Image processing; basically deals with processing of images, pictures, video etc. Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame the output of image processing may be either an image or, a set of characteristics or parameters related to the image. Image processing deals with a variety of aspects like image zooming, image segmentation, image enhancement, video and image compression and transmission (JPEG, MPEG, HDTV, etc.), computer vision (robots, license plate reader, tracking), commercial software's (Photoshop) and many more [5].

Detection and removal of shadow play much important role in the images as well in the videos. Shadows provide rich information about the object shapes and light orientations. Shadows in digital images are troublesome in image processing and pattern recognition. The existence of shadows also causes some serious problems. These problems include the misclassification of background and foreground objects, the merging of objects, changing the shape and color of objects and missing objects.

Shadow often degrades the visual quality of images. So, it is necessary to detect and remove shadows from images. Therefore, shadow detection in an image is an important preprocessing step for improving performance of such computer vision algorithm and image enhancement.

II. OVERVIEW OF SHADOW

A. What is Shadow?

A shadow is created when direct light from any source of illumination is obstructed either partially or totally by an object [7]. If the light energy is fallen less, that area is represented as shadow region whereas if the light energy is emitted more, this area is represented as non shadow region [8].

B. What is Self and Cast Shadow?

Shadow often degrades the visual quality of images. There are two types of shadow, self shadow and cast shadow. Self-shadow is objects itself and another is cast-shadow [9].

Both cast and self shadow has different brightness value. The brightness of all the shadows in an image depends on the reflectivity of the object upon which they are cast as well as the illumination from secondary light sources. Self shadows usually have a higher brightness than cast shadows since they receive more secondary lighting from surrounding illuminated objects.

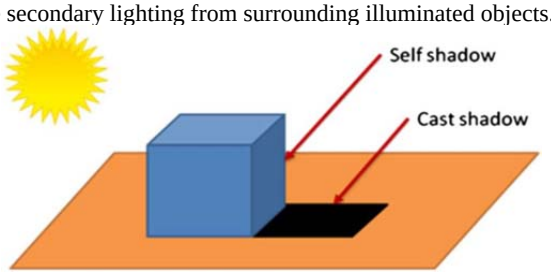

Fig.1. Illustration of cast and self shadows

Again cast shadow can be classified into two parts: umbra and penumbra. The part of a cast shadow where direct light is completely blocked by its object is called umbra, while the part where direct light is partially blocked is called penumbra. These regions are created due to multiple lighting. And the difference between the two lies in the contrast they have to the background.

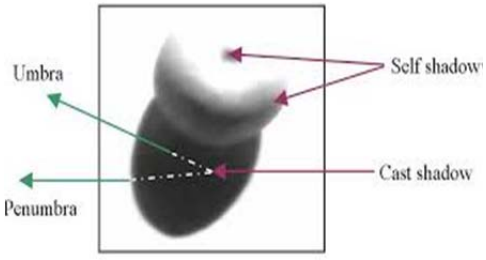

Fig.2. Illustration of umbra and penumbra shadows

C. Properties of Shadow

There are some properties extracted from images which can be used to distinguish between an object, the background and shadow [8]. These properties are listed as following.

- A shadow with lower brightness (illumination) in comparison to the background pixels and this difference changes smoothly between neighbor pixels.
- All RGB values of a shadow are lower than the background in the corresponding pixel.
- In Hue-Saturation-Value (HSV) color space, the hue and saturation components of shadow pixels are a bit smaller than the background.
- Shadow pixels have a lower grey-level (intensity, chromaticity, saturation) from the object and background. In contrast, the object and background often have values with high intensities and the local max value is expected to be large.
- The shadow and the background have the same texture. While the object is texture-rich, a shadow has little texture (texture-less).
- Both a shadow and the background are illuminated by different lights. Shadows illuminated by indirect lights while background illuminated by direct light.
- A shadow has lower boundaries compared to a background.
- An object has acceptable interior edges. In comparison, the shadow region does not have many interior edges. Plus, the exterior edge of a cast shadow is connected to the edges of an object.
- While the shadow and object have same motion, their locations are different.
- Skewness in shadow areas and in non-shadow regions is different, which is a good cue for locating shadows.

III. SHADOW DETECTION AND REMOVAL TECHNIQUES CATEGORIES

As described in [7, 11, 13], shadow detection techniques can be categorized as following:

A. Model Based Techniques

Model based techniques have limited applicability and are applied to specific problems (say aerial images) and simple objects only. These are dependent on prior information about illumination conditions and scene geometry as well as the object which also turns out to be a major drawback.

B. Image based Techniques

In these techniques, certain image shadow properties such as color/intensity, shadow structure and boundaries etc. are used. Nevertheless, if any of that information is available, it can be used to improve the detection process performance.

C. Color/Spectrum based Shadow Detection:

The color/spectrum model attempts to describe the color change of shaded pixel and find the color feature that is illumination invariant. The shadows are then discriminated from foreground objects by using empirical thresholds on HSV color space.

D. Texture based Shadow Detection:

The principle behind the textural model is that the texture of foreground objects is different from that of the background, while the texture of shaded area remains the same as that of the background. The several techniques have been developed to detect moving cast shadows in a normal indoor environment.

E. Geometry based Shadow Detection:

Geometric model makes use of the camera location, the ground surface, and the object geometry, etc., to detect the moving cast shadows.

IV. LITERATURE REVIEW

A brief literature review is needed in order to understand work done by various scholars in this field.

A region-based approach to detect and remove the shadows from an image was proposed by Guo, Dai, and Hoiem [1]. The segmented regions in the image are classified based on relative illumination and using a graph cut, the labeling of the shadow and non-shadow regions is done. The lighting of shadow-pixels is done to recover a shadow-free image. The method “paired region technique”, relies on group soft shadow with non shadow region so unable to detect soft cast shadow. Region growing fails when the pixel intensity varied widely in the shadow regions.

In [2], Ms. Chithra K , Mr. Rahul Ramachandran, Ms. Aleena T .A. describe two methods namely, IOOPL and K-Means clustering. In first method, the Inner Outer Outline Profile lines or IOOPL are obtained by reducing the boundary of shadow inwards and afterwards expanding it outwards. The features of objects on both sides of the boundary are thus obtained. After comparing the inner and outer loop, the color is inserted again and shadow is removed and the output is the image without any shadows. While, in the K-MEANS clustering methodology the main parameter for identifying the data points into separate clusters is done by keeping certain distance between each data point. After clustering the data points, the points that show the shadow region and the mask are compared which gives us the perfect shadow area. Compared to IOOPL method, clustering using K-MEANS method is better.

D. Usha Nandini, Dr. Ezil Sam Leni, A. Mary Binu [10] proposed a method of combining intensity with TAM image. Shadow detection based on TAM information and the accuracy of shadow is improved by intensity information. By combining TAM and intensity, it is improving quality of results. It avoids segmentation and requires one threshold. TAM used to detect shadows that describes attenuation relationship between shadow and non-shadow regions. It requires rough segmentation and four thresholds. It fails to give accurate results in complex scenes. All simple and complex shadow in outdoor images is detected and comparisons validated its effectiveness.

Xiaoyan Xu and Xiaoming Liu [12] proposed a novel and fast shadow detection method based on the Tricolor Attenuation Model. Analyze the spectral property of outdoor light sources to estimate the parameters of TAM. Then method is proposed by integrate the TAM feature and intensity information. Method can extract shadows in only a single and uncelebrated image that takes advantage of the spectral property. Use only a single color image when detect the shadow in it without needing any prior knowledge.

Prajkta Khaire and Manoj Sabnis, [13] proposed two techniques to detect the shadows of outdoor images. Outdoor images which have a constant background but the lighting conditions are variable are used. In first technique, global thresholding. Measure the ratio map by using the H and V values of HSV. Afterwards, global image threshold is obtained from Otsu's method and binary image from ratio map is obtained. Gradient map is found using the Sobel operator and V of HSV is obtained. Thus, the shadow area is obtained from the gradient map drawn using Global Image Threshold. In second technique, HSV image gets converted to RGB's color image. Ratio map R is constructed. Afterwards, threshold is calculated using the Otsu Method. Then threshold is performed on image to get the resultant binary image. Region Labeling to eliminate any smaller regions to obtain the local threshold from Otsu's method and local threshold is used to get shadow area of the image.

Ashraful Huq Suny and Nasrin Hakim Mithila [4] proposed a simple method to detect and remove shadows from a single RGB image. A shadow detection method is selected on the basis of the mean value of RGB image in A and B planes of LAB equivalent of the image and shadow removal method is based on the identification of the amount of light impinging on a surface. The lightness of shadowed regions in an image is increased and then the color of that part of the surface is corrected so that it matches the lit part of the surface. The advantage of this method is that removing shadow does not affect the texture and all the details in the shadowed regions. They describe a shadow removal method for real images based on increasing the lightness of shadowed regions in an image. The color of that part of the surface is then corrected so that it matches the lit part of the surface. The algorithm proposed worked successfully in removing both partially lit and non-lit regions.

Priya Garg and Kirtika Goyal [6] proposed algorithm uses the chromaticity to detect and remove the shadow. Find the invariant direction, and so grayscale and hence an L1chromaticity intrinsic image that is shadow-free, without any need for a calibration step or special knowledge about an image.

In [3], Kaushik Deb and Ashraful Huq Suny proposed method using the luminance, chroma: blue, chroma: red color space to detect and remove shadows. Different intensities in the YCbCr color space are proposed for detecting shadows. A shadow density model is used after shadows are determined. From the shadow density model, segmentation performed and sorted into several segments that have the similar density. In the end, the shadows found are removed by relighting every pixel in the YCbCr color space and fixing the color of the regions having shadow in the RGB color space. There is no severe transition between both the shadow and non-shadow parts, and the shadowed area remains unchanged. Proposed framework effectively succeeded in removing shadows from multiple textured images.

In [14] G. Gayathri presented the method in which to get shadow detection result, image segmentation considering shadows is applied first. Then, suspected shadows are selected through spectral features and spatial information of objects, and false shadows are ruled out. For shadow removal, after the homogeneous sections have been obtained by IOOPL matching, relative radiation correction for the objects is performed in order to remove the shadows.

The tricolor attenuation model (TAM) was proposed to detect shadows in a single image. Shadow identification was done, followed by generation of an invariant image, on which segmentation was performed. TAM was then used to detect the shadows, but dark areas were misclassified as shadows [9].

TAM uses the concept of intensity attenuation of pixels in the shadow region which is different for the three color channels. In [9], methodology for shadow detection is proposed by enhancing the TAM image using adaptive histogram equalization. This improves the contrast of the TAM image and thereby improving the quality of detection results.

As described in [5, 7, 8], there are various methods and techniques has been presented during the last few years. Proposed a various methods/algorithms/techniques for shadow detection and removal in indoor, outdoor scene, traffic surveillance images, all types of shadowed image. etc. are described in table I:

V. CONCLUSION

It is observed that Shadows are everywhere around us and we are rarely confused by their presence. Tracking or detection of moving objects is at the core of many applications dealing with image sequences. One of the main challenges in these applications is identifying shadows which objects cast and which move along with them in the scene. Shadows cause serious problems while segmenting and extracting moving objects, due to the misclassification of shadow points as foreground. In this paper, we have provided a comprehensive survey of shadow detection and removal in images etc. survey is done on various types of images real time application or traffic images. A survey on various shadow detection and removal methods and algorithms.

TABLE I VARIOUS SHADOW DETECTION AND REMOVAL TECHNIQUES/ALGORITHMS

Sr. No	Technique	Key Idea	Advantage	Disadvantage
1	Chromacity based	Hue and saturation combined together are known as chromaticity. RGB is converted to HSV or HSI.	Can select proper features and parameters for shadow. Highly accurate.	Tends to misclassify.
2	Region Growing Based	Seed points are selected. These are groups of pixels with high confidence of being shadow (say according to distance) and shadow area extended, growth controlled by connectivity	Can correctly separate shadow and non-shadow regions. Edges are crisp. Good shape matching of results.	Region growing, failed when the pixel intensity varied widely in the shadow region.
3	Dual-pass Otsu method	Pixels value is separated into high and low level intensity. Threshold is set to distinguish between self and cast shadow. Cast shadow pixels are than replaced by background pixels.	It is computational inexpensiveness.	Performance is poorest.
4	Color based	Color tune value of shadow and background same but different intensity. Color differences of shadowed pixel and background pixels as well as illumination invariance are used.	Reliable technique for colored images.	Fails when intensity of shadow and background is same, color of objects same as or darker than background.
5	Geometry Based	The orientation, size and even shape of the shadows can be predicted with proper knowledge of the illumination source, object shape and the ground plane.	This method revolves around the Geometric model in objects in the scenes change in model leads to ineffective results.	Method will be ineffective when geometric representation of object will change.
6	Based on Intensity Information	Standard deviation is calculated for ratio value. Conditions are set for a shadowed pixel.	Function for pixel intensity is estimated directly from the data without any other assumptions	Actually the pixel intensity value is susceptible to Illumination changes.
7	Threshold based	Predefined threshold level based on bimodal histogram used to determine shadow and non-shadow pixels.	Simple and fast.	Requires post-processing as results might be incoherent or blurred and may have holes, noise etc.
8	Color and Statistical Information	Depending on the complexity of lighting conditions, different color models are used.		It takes more time for computation.
9	Segmentation based	Classification techniques like SVM are used based on the properties possessed by shadow pixels.	Can detect probable shadow boundaries accurately. Simple and easy to implement.	There are chances Of misclassification. Shadows of small objects are missed sometimes.
10	Texture-based Shadow Detection	Takes in account the similarity between background and shadow texture as well as the difference in foreground and background	Best for indoor scenes.	Difficult to implement. Poor performance for outdoor scenes as texture capturing is difficult.
11	Edge based	It used when Brightness changes sharply or has discontinuity and to detect missing pixels.	An edge gives the Boundary between shadow and the background.	It is not suitable for small objects and their shadows.

12	Edge subtraction and morphology	Canny edge detection is used to detect background edge and foreground edge. Resultant edge image is calculated by difference of both background and foreground edge. Centroid of vehicle-shadow region is found by formula.	Method is best when scenes containing light and dark vehicles.	It is most computation.
13	Gradient-based background subtraction	Fixed threshold is set for T vertical and T horizontal, boundary of object is extracted using neighbored ratio. Foreground is extracted by using mixture of Gaussians.	Location is used to detect the shadow. Shadow detection is done correctly. Real time applications take advantage of this algorithm.	
14	Illumination Assessment Method	Presence of shadow in object is confirmed by illumination assessment method, cast shadow is separated from the object by subtracting background edges from foreground edges. Stationary Cameras are taken.	It takes Less Processing time. Only foreground figure is considered. This technique examines presence of shadow.	It ignores some application not applied for all kind of application.
15	Hierarchical Graph cut	Image is over segmented to produces the set of super pixels, lazy snapping is used to Specify shadow, non-shadow, and background region.	This method solves problems 3 to 16 times faster than alpha expansion method. It solves multi-labeling problems. Image restoration shadow removal and stereo matching is done by hierarchical graph cut algorithm.	An initial value is required. Only single image is considered to remove the shadow.
16	Harris Algorithm	Neighboring point eliminating method used to detect corner efficiently.	More efficient then Susan algorithm. It avoids clustering.	
17	Susan Algorithm	Video highway data is taken with avi format, edge is detected from Susan method and mixed gauss. Background is obtained by distribution.	Speed is enhanced. Method is simple and convenient, low complexity, high adaptability and high accuracy. It gives good detection effect.	
18	Based on Photometric Invariants Information	Intensities in the neighbor pixels in the foreground region is equal to the ratio of neighbor pixels in the background image in the presence of shadow.	Performance is better by using robust features. It takes little time. The average time consumption is good for real-time application.	
19	Partial Differential Equations	Different filters are used to smooth the image. Gradient vector is used to detect shadow. Image information is used.	Shadow detection is successful and effective.	Does not perform well on edges which span large gaps or holes.
20	Gray-scale Based	Comparison between current frame and background helps in shadow detection as only luminance information is present. Image quotient, texture, gradient images etc. are used.	Save computation time.	Depends on synthetic training
21	Retinex theory based	Comparison between retinex enhanced and original images done as human-vision-based retinex can enhance shadow regions naturally.	Both umbra and penumbra regions can be removed, hard shadow edges can be detected.	Over-enhancement of shadows may cause fine texture to disappear.

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