Survey on Shadow Detection and Shadow Removal

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Abstract— **In real world, shadow causes serious problems while segmenting and extracting the foreground. Shadow can also distort the shape of object if shadow of one object is projected on another object. In some cases shadows can yield additional information regarding the scene and lighting conditions and hence can be considered desirable. So the objective is to create a system that can automatically detect shadow regions and then remove shadow from single images of natural scenes. Numbers of approaches are proposed in the literature to address such problems such as region based approach in which image is segmented into regions then classified and matting is used to recover shadow-free image. This paper is aimed to provide a survey on various 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.**

Index Terms— **Shadow detection, shadow removal, segmentation and matting.**

I. Introduction

SHADOWS, created wherever an object obscures the light source, are an ever-present aspect of our visual experience. Shadows can either aid or confound scene interpretation, depending on whether we model the shadows or ignore them. If we can detect shadows, we can better localize objects, infer object shape, and determine where objects contact the ground. Detected shadows also provide cues for illumination conditions and scene geometry. But, if we ignore shadows, spurious edges on the boundaries of shadows and confusion between albedo and shading can lead to mistakes in visual processing. For these reasons, shadow detection has long been considered a crucial component of scene interpretation. Yet despite its importance and long tradition, shadow detection remains an extremely challenging problem, particularly from a single image.

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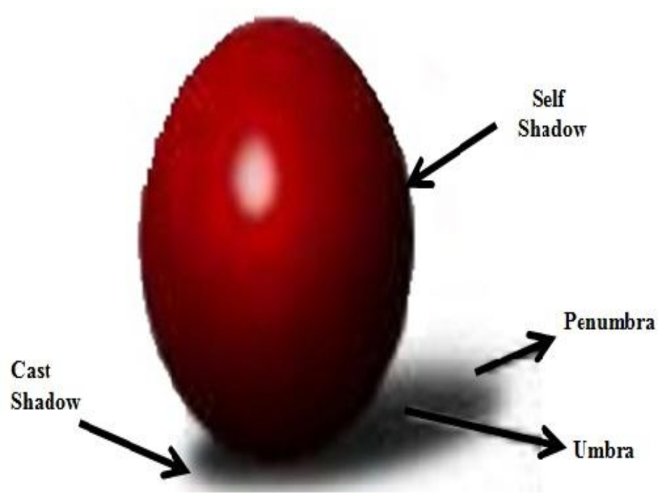
II. FUNDAMENTALS OF SHADOW

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. The shadow regions, however, are illuminated by ambient light. Typically, shadows can be divided into two major classes: cast shadow and self shadow. Cast shadow is the dark area projected by the object in the direction of direct light. Cast shadows occur when a shadow falls on object whose normal is facing toward the light source. Cast shadows whereas have clearly defined boundaries. The cast shadow is usually further divided into two parts, umbra and penumbra. These regions are created due to multiple lighting. And both have different contrast to the background. Umbra represents the shadow region where the primary light source is completely obscured and penumbra is the region around the edge of a shadow where the light source is only partially obscured. Self shadows are a specific case of cast shadows that occur when the shadow of an object is projected onto itself. A self shadow occurs on the portion of object that is not illuminated by direct light. Self shadows generally do not have hard boundaries and hence are referred to as vague, the reason being gradual intensity change.



B. *Useful features for shadow detection*

1) Intensity: The simplest assumption that can be used

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to detect cast shadows is that regions under shadow become darker. Furthermore, there is a limit on how much darker they can become. These can be used to predict the range of intensity reduction of a region under shadow which is often used as a first stage to reject non- shadow regions.

2) Chromacity: Most shadow detection methods based on spectral features use color information. They use the assumption that regions under shadow become darker but retain their chromacity. Chromacity is a measure of color that is independent of intensity. For instance, after green pixel is covered by shadow it becomes dark-green, which is darker than green but has the same chromacity.

3) Physical properties: The linear attenuation model assumes that illumination source produces pure white light which is often not the case. In outdoors environments, the two major illumination sources are the sun (white light) and the light reflected from the sky (blue light). Normally, the white light from the sun dominates any other light source. When the sun light is blocked, the effect of sky illumination increases, shifting the chromacity of the region under shadow towards the blue component.

4) Geometry: In theory, the orientation, size and even the shape of the shadows can be predicted with proper knowledge of the illumination source, object shape and the ground plane. Some methods use this information to split shadows from objects.

5) Textures : Some methods exploit the fact that regions under shadow retain most of their texture. Texture-based shadow detection methods typically follow two steps: (a) selection of candidate shadow pixels or regions and (b) classification of the candidate pixels or regions as either foreground or shadow based on texture correlation.

III. DIFFERENT SHADOW DETECTION METHODS

[1] "Paired Regions for Shadow Detection and Removal", Ruiqi Guo, Qievun Dai and Derek Hoiem, IEEE transactions on pattern analysis and machine intelligence, vol.35, Dec2013.

In this paper, Classification based / Segmentation based method is proposed by Guo et.al [1]. Region based approach is employed. Classification techniques like SVM are used based on the properties possessed by shadow pixels. They considered individual regions separately as well as performed pair-wise classification. By using soft matting to remove shadows, the lighting conditions for each pixel in the image are better reflected.

Advantages:

This method can detect probable shadow boundaries accurately as well as it is simple and easy to implement. To improve robustness, they used data-driven approach for learning to detect shadows based on training images. Also it restricts comparisons to regions with the same material to improve robustness in complex scenes, where material and shadow boundaries may coincide.

Disadvantages:

There are chances of misclassification. Shadows of small objects are missed sometimes. To determine if region is in shadow must compare the region to others that have the same material and orientation. Region based shadow detection enables to pose shadow removal as a matting problem. However, method depends on user input of shadow and non-shadow regions, while automatically detect and remove shadows in a unified framework.

[2] "A Bi-Illuminant Dichromatic Reflection Model for Understanding Images", B.A. Maxwell, R.M. Friedhoff, and C.A. Smith, Proceeding IEEE Conference Computer Vision and Pattern Recognition, 2008.

In this paper, Retinex theory based method is proposed by Maxwell et.al [2]. In this retinex enhanced and original image is compared. They used Shafer's dichromatic reflection model, a physics-based model of reflection to separate different types of reflection on a single surface. Shafer's model proposed that inhomogeneous dieletrics such as paints, ceramics and plastics exhibit two types of reflection, surface reflection and body reflection, and that the different types of reflection caused specific types of changes in appearance.

Advantages:

Using retinex theory based method both umbra and penumbra regions can be removed and hard shadow edges can be detected. The model is the basis for a new 2-D chromaticity space that is illumination invariant for a direct and ambient illuminant pair. Also for a spectral ratio calculation that measures the properties of light field irrespective of underlying material reflectance in the scene.

Disadvantages:

In this over-enhancement of shadows may cause fine texture to disappear. It depends on bi-directional reflectance distribution function [BRDF] which can divide into body and surface reflection components. Tasks such as segmentation and object recognition become more difficult because simple assumptions about how material colors behave under varying illumination create apparently random effects.

[3] "Detecting Ground Shadows in Outdoor Consumer Photographs", J.-F. Lalonde, A.A. Efros, and S.G. Narasimhan, Proceeding 11th European Conference Computer Vision, 2010.

In this paper, geometric properties based method is proposed by Lalonde et.al [3]. In this sets of geometric features are matched. It detects ground shadows with good accuracy, shadows that are not on the ground exhibit significantly larger appearance variations so detecting them will be challenging.

Advantages:

It detects ground shadows with good accuracy and provides effective detection under simulated and controlled environment. This method revolves around the geometric model in objects in the scenes change in model leads to ineffective results. This method can be used as a stand-alone shadow detector and it can also be tightly integrated into higher level scene understanding tasks.

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Disadvantages:

It requires huge computation time and depends on object-scene relationship. It is not feasible for spatial, real-time cases. This method revolves around the geometric model in objects in the scenes change in model leads to ineffective results so it will be ineffective when geometric representation of object will change. In this, types of materials constituting the ground in outdoor scenes are limited to asphalt, brick, stone, mud, grass, concrete.

[4] "Learning to Recognize Shadows in Monochromatic Natural Images", J. Zhu, K.G.G. Samuel, S. Masood, M.F. Tappen, Proceeding IEEE Conference Computer Vision and Pattern Recognition, 2010.

In this paper, gray-scale based method is proposed by Zhu et.al [4]. In this comparison between foreground and background helps in shadow detection as only luminance information is present. Without chromatic information, shadow classification is very challenging because the invariant color cues are unavailable. Natural scenes make this problem even harder because of ambiguity from many near black objects so they addresses the problem of recognizing shadows from monochromatic natural images. In this learning-based approach is used for detecting shadows in a single monochromatic image and single-pixel classification strategies.

Advantages:

This method saves the computation time. It uses both shadow-variant and shadow-invariant cues. Features expressing illumination, textural and odd derivative characteristics can successfully identify shadows. In this Boosted Decision Tree (BDT) integrated with Binary Conditional Random Field (BCRF) using 2 levels of segments achieves highest recognition rate. Using the cues the method can successfully identify shadows in real-world data where color is unavailable. Single-pixel classification strategies work well.

Disadvantages:

It depends on synthetic training. It must perform over-segmentation using intensity values to include the features from homogeneous regions. To capture the cues across shadow boundaries, statistics of neighboring pairs of shadow/non-shadow segments must be gathered from all individual images in the dataset.

IV. DIFFERENT SHADOW REMOVAL METHODS

[1] "On the Removal of Shadows from Images", G.D. Finlayson, S.D. Hordley, C. Lu, and M.S. Drew, IEEE Transactions Pattern Analysis and Machine Intelligence, volume 28, Jan. 2006.

In this paper, color and statistical information method is proposed by Finlayson et.al [5]. Probabilistic function from illumination model helps decide shadow and non-shadow pixels. This method removes shadow edges from edge-map of original image by edge in-painting. They also proposed a method to reintegrate, this threshold edge map, thus deriving the 3D shadow-free image. They introduced three different shadow-free image representations: 1D invariant based on simple constraints on lighting and cameras, 2D chromaticity representation which is equivalent to the 1D representation but with some color information retained and 3D full color image.

Advantages:

It's efficient shadow removal method that yields very good performance. The 2D chromaticity representation of images is very useful and additionally removing shadows from this representation, increases value of a chromaticity representation. For many surfaces, resulting chromaticity image is close to original with advantage that the representation is shadow-free. The procedure for deriving each of the three representations is automatic.

Disadvantages:

It is poorly conditioned and requires high cost of computation. Identifying shadows and accounting for their effects is a difficult problem since a local change in both the color and intensity of the scene illumination affects the shadow. The derivation of one-dimensional image representation is invariant to both illumination color and intensity. Process of transforming original RGB representation to 1D invariant representation might also results into undesirable artifacts for some images. For each of three representations, number of parameters must be specified. In all cases, there is need to determine the direction of illumination change.

[2] "Entropy Minimization for Shadow Removal", G.D. Finlayson, M.S. Drew, and C. Lu , International Journal Computer Vision, volume 85, 2009.

In this paper, chromaticity based method is proposed by Finlayson et.al [6]. Hue and saturation combined together are known as chromaticity. RGB is converted to HSV or HSI. They presented a method based on entropy minimization for finding the invariant direction, and thus a gray scale and L1-chromaticity intrinsic image that is independent of lighting and shadow free, without any need for a calibration step or special knowledge about an image. Quadratic entropy definition provides a stable and efficient vehicle for calculating the minimum-entropy lighting invariant direction.

Advantages:

It can select proper features and parameters for shadow. It is highly accurate. It does not require calibration step or special knowledge about an image. The method leads to good re-integrated full-color shadow free images. Cameras supply images and videos that are compressed as well as greatly processed away from being linear images. Under such processing, JPEG images exhibit a strong entropy minimum.

Disadvantages:

It tends to misclassify. The extra edges introduced due to blocking effects make re-integration more difficult. It have limited applicability to degree for scenes. The method is not suitable for small pixel values under bright lighting.

[3] "Fast Re-Integration of Shadow Free Images", C.

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Fredembach and G.D. Finlayson, Proceeding Color Imaging Conference ,2004.

In this paper, edge based method is proposed by Fredembach et.al[7]. They treat shadow removal as reintegration problem based on detected shadow edges. It used when brightness changes sharply or has discontinuity and to detect missing pixels. This is mainly based on invariant images to find material edges in the image and a thresholding operator to distinguish between material and shadow edges. It uses a small number of non-random paths, each of which is a tour the size of image.

Advantages:

It is an effective and fast reintegration method. An edge gives the boundary between shadow and the background. Image reintegration can be simplified to 1-D problem. This reduction in dimensionality allows for a much less complex and less costly reintegration procedure. It uses the average values over several paths that greatly improve the quality of the output image.

Disadvantages:

It is not suitable for small objects and their shadows. It cannot take care of the visual artifact that occurs after the reintegration. The structural artifacts remain after the reintegration. In the 2D case, there is a smudging on the shadow boundaries and the shadow region looks some-what artificial. In the 1D case, reintegrated image exhibits structural artifacts due to the paths construction.

[4] "Shadow Removal Using Intensity Surfaces and Texture Anchor Points", E. Arbel and H. Helor, IEEE Transactions Pattern Analysis and Machine Intelligence, volume 33, June 2011.

In this paper, texture based method is proposed by Arbel et.al[8]. They uses cubic splines to recover the scalar factor in penumbra regions. Proposed method for enhancing shadow-free regions is based on assumption that two matching patches, one inside the shadow-free region and one outside the region, should have similar statistical behavior. This method is not restricted to images with certain illumination conditions such as outdoor scene images. Shadow detection algorithm can be used that best suits the illumination conditions in a given image. Main approach is that image data should not be nullified at any stage of the process; rather, image content should be preserved and if necessary it should be modified.

Advantages:

The method removes non-uniform shadows on curved and textured surfaces. The method produces high quality results on many types of shadow images, coping with some fundamental problems in shadow removal. Proposed shadow-free region enhancement process increases robustness in handling shadow images that have undergone image processing transformations in shadow regions, as well as shadow images with noise. Despite the highlight region exhibits high non-uniformity, the proposed method can be used without any changes to recover a highlight-free image.

Disadvantages:

It's computation time is dependent on the size of the shadow region that affects approximation time. The seam between shadow and objects seems artificial due to shadow boundaries that coincide with object boundarie. Labeling penumbra pixels by direct thresholding produces many false alarms and misses. It requires the user to supply initial cues for the system.

V. CONCLUSION

In this paper, we have described various methods available in literature for shadow detection and shadow removal. First, the fundamentals of shadow and shadow formation as well as the useful features for shadow detection have been discussed. Secondly, we have provided a comprehensive survey of shadow detection methods and shadow removal methods for different types of images by discussing their advantages and disadvantages. Shadow detection can be performed by either using the methods described above individually or in combination with one or more of the techniques mentioned above.

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[8] E. Arbel and H. Helor, "Shadow Removal Using Intensity Surfaces and Texture Anchor Points", IEEE Transactions Pattern Analysis and Machine Intelligence, volume 33, June 2011.

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