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A Review on various widely used shadow detection methods to identify a shadow from images

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Abstract- In this paper, we address the different shadow detection methods and algorithms for both still and moving images as well as give a brief description of the advantages and disadvantages of each method. Shadow detection and removal is an important step in visual surveillance and monitoring systems. Shadow points are often misclassified as object points causing errors on localization, segmentation and classification of objects. Many algorithms and methods have been developed for different environmental conditions to detect shadow from the images. We will review some widely used methods how to detect shadows and extract it avoiding loss of texture information.

Index Terms- Shadow detection, Shadow removal, Image processing, Intensity, Texture;

I. INTRODUCTION

Shadow detection is becoming an active and attractive research area for many image processing applications such as traffic surveillance, object recognition and image segmentation. Shadows can cause objects merging, shapes distortion and object loss. Shadow distorts the object's shape, so that the use of shape recognition techniques became not reliable (shadows and objects are merged in a single blob). In addition, shadow maybe classified as a totally erroneous object in the scene [1]. For these reasons, a simple, reliable and accurate method in shadows identification is required.
In our survey, we study the more prominent shadow detection methods published during the last decade and show the strengths and weaknesses of each method.

General concepts of shadow:

What is a shadow? A shadow happens when an object partially or totally occluded by direct light from a source of illumination. Shadows often degrade the visual quality of images. Shadows can be divided two types: self and cast shadows. A *self shadow* occurs in the portion of an object which is not illuminated by direct light. A *cast shadow* is the area projected by the object in the direction of direct light [2].

Self shadow and cast shadow are shown in fig.1. Self and cast shadows produce different brightness values. Self shadows (also called attached shadows) usually have a higher brightness than cast shadows since they receive more secondary lighting from surrounding illumination objects. [3]. In addition, self-shadows are vague shadows and do not have clear boundaries. However, cast shadows are hard shadows and always have a violent contrast to background

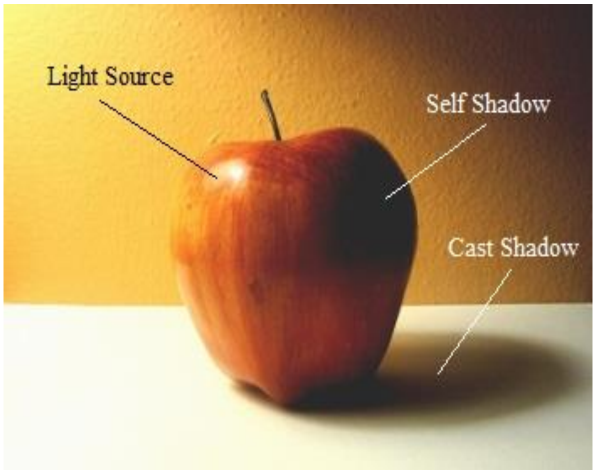

Fig.1 Shadow is divided as self and cast shadows

Based on the intensity, cast shadow can be further divided into umbra (hard) and penumbra (soft) region, as depicted in fig.2. The soft shadows retain the texture of the background surface, whereas the hard shadows are too dark and have little texture. Thus the detection of hard shadows is complicated because they can be mistaken for dark objects rather than shadows.

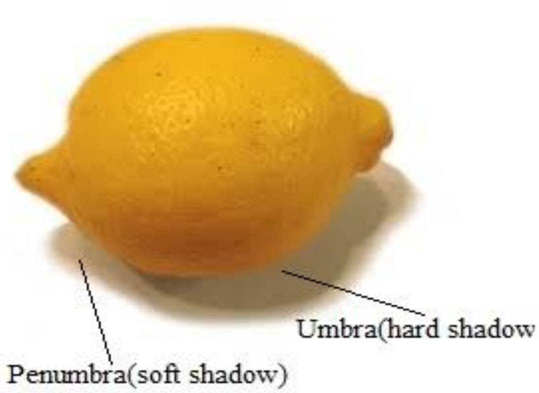

Fig.2 Types of shadow (umbra and penumbra)

Though most of the shadow detection methods need multiple images for camera calibration, the best technique must be able to extract shadows from a single image [4].

SHADOW DETECTION

The shadow detection process consists of two challenging subtasks: detecting the shadowed region and restoring the illumination in that region. The detection task involves some degree of image understanding in order to determine whether a pixel is dark due to a shadow or the reflectance at the corresponding scene point. Accomplishing this task requires making some assumptions about the shadowed surfaces in the scene and asking the user for some hints. The restoration task is also challenging, as it attempts to eliminate any perceivable differences between the originally lit and the restored parts of the images. In particular, it is difficult to avoid differences in local contrast and in the amount of noise between two regions [5].

Previous Works

It is easier for the human eye to distinguish shadow from objects. However, identifying shadows by computer is **I.** a challenging research problem. It is therefore of great importance to discover ways of properly detecting shadows and removing them while keeping other details of the original image intact. A significant amount of research has been performed on detecting and removing shadows over the past few years.

The Pyramid-Based shadow removal (PBSR) was proposed [5] to detect and remove shadows from a single image. In this approach, first identify shadowed and lit areas on the same surface in the scene using an illumination-invariant distance measure. These areas are used to estimate the parameters of an affine shadow formation model. A novel pyramid-based restoration process is then applied to produce a shadow-free image, while avoiding loss of texture contrast and introduction of noise.

The main goal of this method is a nearly-automatic tool capable of producing high-quality shadow free images. PBSR method is applicable to cast shadows resulting from the occlusion of a single primary light source. Shor et al. in [5] further assume that each shadow to be removed is cast onto a scene surface (a region with coherent color and texture) that has both shadowed and unshadowed parts.

Prati et al [6] evaluated the usefulness of several shadow detection methods using the following two metrics, which indicate the shadow detection rate (η) and the shadow discrimination rate (ξ):

$$\eta = \frac{TP_S}{TP_S + FN_S} \quad \text{and} \quad \xi = \frac{TP_F}{TP_F + FN_F} \qquad (1)$$

Here TP and FN stand for true positive and false negative pixels with respect to either shadows (S) or foreground objects (F). The shadow detection rate is concerned with labeling the maximum number of cast shadow pixels as shadows. The shadow discrimination rate is concerned with maintaining the pixels that belong to the moving object as foreground. Current shadow detection methods present a compromise between the two rates [6].

In [7] authors describe new shadow detection method that is able to achieve both good shadow detection and discrimination rates, leading to improved tracking in surveillance scenarios. The proposed method first uses chromaticity information to create a mask of candidate shadow pixels, followed by employing gradient information to remove foreground pixels that were incorrectly included in the mask.

The method has five steps: (1) pre-selection of shadow pixels based on chromaticity invariance, (2) grouping of shadow pixels into candidate shadow regions, (3) selection of pixels with significant gradient magnitude in each region, (4) calculation of the gradient direction distance between the given frame and the background reference image for each selected pixel, (5) for each candidate shadow region, correlation of the gradient direction between the given frame and the background image to determine which regions are shadows. The five steps are described in more detail and the whole process is clearly explained in [7].

Widely used shadow detection algorithms.

Texture-based shadow detection method

Texture-based shadow detection methods typically follow two steps: **(1)** selection of candidate shadow pixels or regions, and **(2)** classification of the candidate pixels or regions as either foreground or shadow based on texture correlation [8]. Selection of the shadow candidates is done with a weak shadow detector, usually based on spectral features. Then, each shadow candidate is classified as either object or shadow by correlating the texture in the frame with the texture in the background reference. If a candidate's texture is similar in both the frame and the background, it is classified as shadow. First, for each candidate region, the gradient magnitude $|\nabla p|$ and gradient direction θp at each pixel p = (x, y) are calculated using:

$$|\nabla p| = \sqrt{\nabla x^2 + \nabla y^2} \qquad (2)$$

$$\theta p = arctan2(\nabla_y / \nabla_x) \qquad (3)$$

where ∇_y is the vertical gradient (difference in intensity between the pixel and the pixel in the next row), while ∇_x is the horizontal gradient. The function arctan2(·) is a variant of arctan(·) that returns an angle in the full angular range [-π, π], allowing the gradient direction to be treated as a true circular variable. Only the pixels with $|\nabla_p|$ greater than a certain threshold τ_m are taken into account to avoid the effects of noise, which is stronger in the smooth regions of the frame.

Techniques	Advantages	Disadvantages	Reference
Texture-based methods	Do not depend on colors, robust to illumination changes	Multiple processing steps	[7],[8]
Chromacity-based methods	The fastest to implement and inexpensive	Sensitive to pixel-level noise	[9]
Physical methods	Significantly faster in a real-time	Need more operations	[10],[11]
Geometry-based method	Work directly in the input frame	Fails when the shadows have the same orientations	[12]

Table 1: Advantages and Disadvantages of the Techniques

The Table 1 consists of current widely used methods with their advantages and drawbacks. So we can conclude various processes can be used for shadow detection and elimination and similarly can be improved by developing new algorithms to introduce new methods. The following criteria should be given importance for discovering new methods [13].

1) Shadow detection and removal should be sturdy, fast and automatic.

2) The algorithms/methods should reduce or completely remove the shadow from images and improve its image quality.

3) While removing the shadow without removing or losing the information or data is a major criterion to be taken in mind [14]. These recommendations may also assist in improving the shadow removal algorithm.

II. CONCLUSION AND FUTURE DIRECTIONS

In this paper, we described efficient methods for segmenting cast shadows in both still and moving images. Among variety of methods discussed, Texture-based shadow detection method is a potentially powerful technique for detecting shadows as textures are highly distinctive, do not depend on colors, and is robust to illumination changes. Pyramid-Based algorithm is also very efficient among all methods and best suited to remove shadows indoor and outdoor environmental images and introduces the noise in the scene; it uses the illumination invariant technique to avoid the loss of texture contrast similarly for the video surveillance image scenes. The main conclusion is that only the simplest methods are suitable for generalization, but in almost every particular scenario the result could be significantly improved by adding assumptions.

As mentioned above, all methods have strengths and weaknesses, in the future work we are going to upgrade and improve one of the shadow detection algorithms and implement in various fields as well as in computer vision applications, in order to identify the shadow regions.

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