International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 3, Issue 4, April 2014

A Survey on Shadow Detection Methods

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***Abstract*—Shadows in images are indispensable yet sometimes undesirable as they can deteriorate results of computer vision algorithms. Also, in some cases shadows can yield additional information regarding the scene and lighting conditions and hence can be considered desirable. Shadow detection is the first step to shadow analysis and image processing in a number of applications. This paper presents a review of the existing literature in this area. Although it is not possible to review all the related work, an effort has been done to list some of the very crucial techniques.**

***Index Terms*— Colour space models, Model based techniques, Property based techniques, Shadow detection.**

I. INTRODUCTION

A shadow which is known to be caused by the interaction of light with objects claims a fraction of the image surface. Shadows in images hold importance for a variety of reasons. On one hand, shadows may lead to the failure of image analysis processes and also cause a deterioration in the quality of information which in turn leads to problems in implementation of algorithms say for scene understanding, object recognition and many other applications. But, on the other hand, they aid information as cues in building detection, path finding etc. [1].

Since, shadows sometimes create undesirable effects on images, shadow reconstruction is considered important, and detection of shadows is the first step towards the goal. Also, in cases where they act as an aid, shadow detection in images plays a vital role. It is used for land monitoring, remote sensing, change detection, image segmentation, face recognition etc.

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. Such occlusion of path of light leads to the formation of shadows as light always travels in straight lines and cannot bend [2].

Shadows usually claim most of the space behind opaque objects when light falls on them. Cross section of a shadow is seen as a projection- an overturned one, of the object which blocks light. It is two dimensional. Hence, when light is blocked, an image is produced known as shadow.

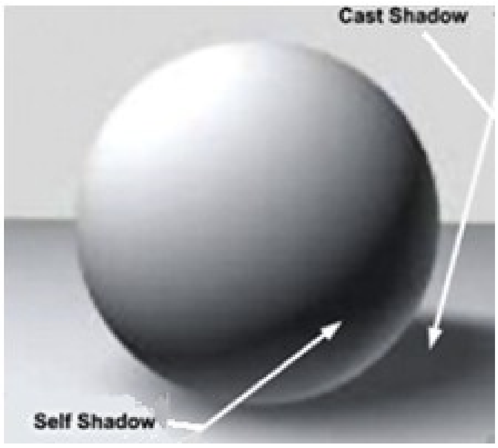

Fig. 1: Types of Shadow

Shadows can be classified as- self shadows and cast shadows. A self shadow is one which falls on a part or portion of object whereas cast shadows do not fall on object but are projected on surrounding surfaces[1]. Cast shadows are of two types- umbra and penumbra. These regions are created due to multiple lighting. And the difference between the two lies in the contrast they have to the background. Self shadows generally do not have hard boundaries and hence are referred to as vague, the reason being gradual intensity change. Cast shadows whereas have clearly defined boundaries [3].

B. Color Space Models

Color space models are used to produce photometric invariant images and they play a very important role in shadow detection. An overview of some color space models as described in [4] and [5] is given in Table I.

Manuscript received April, 2014.

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TABLE I. AN OVERVIEW OF VARIOUS COLOR SPACE MODELS

MODEL	CONVERSION FROM RGB
HSI	If G≥B; $H = \cos^{-1}[(R - 0.5G - 0.5B)R2+G2+B2+-RG-RB-GB]$ if B>G; $H = 360 - \cos^{-1}[(R - 0.5G - 0.5B)R2+G2+B2+-RG-RB-GB]$ $S = 1 - (\min(R,G,B)/\frac{(R+G+B)}{3})$; $I = (R + G + B)/3$
HSV	If G≥B; $H = \cos^{-1}[(R - 0.5G - 0.5B)R2+G2+B2+-RG-RB-GB]$ if B>G; $H = 360 - \cos^{-1}[(R - 0.5G - 0.5B)R2+G2+B2+-RG-RB-GB]$ $S = 1 - (\min(R,G,B)/\max(R,G,B))$; $V = \max(R,G,B)/255$
$C_1C_2C_3$	$C_1 = \tan^{-1}\frac{R}{\max(G,B)}$; $C_2 = \tan^{-1}\frac{G}{\max(R,B)}$; $C_3 = \tan^{-1}\frac{B}{\max(R,G)}$
YIQ	Y = 0.299*R + 0.587*G + 0.114*B ; I = 0.596*R – 0.275*G – 0.321*B ; Q = 0.212*R – 0.523*G + 0.311*B ;
YC_bC_r	Y = 0.257*R + 0.504*G + 0.098*B + 16 ; C_b = -0.148*R – 0.291*G +0.439*B + 128 ; C_r = 0.439*R – 0.368*G –0.071*B + 128

In the table above the symbols stand for, R=Red, G=Green, B=Blue; H=Hue, S=Saturation, V=Value, I=Intensity; C_1,C_2,C_3 represent first, second and third chrominace respectively ; Y stands for luminance, I for in-phase and Q for quadrature; in YC_bC_r, Y represents luminance, and C_b ,C_r represent chrominance.

II. VARIOUS SHADOW DETECTION METHODS

As described in [2], shadow detection techniques can be categorized as: model based and property based as proposed.

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 [1]. These techniques revolve around the idea that the desired structures do have repetitive geometries. Hence, probabilistic models could be easily implemented for segmentation purpose. Also, various sets of geometric features are matched with three dimensional object models [2].

B. Property Based Techniques

Property based shadow detection methods have fewer limitations as compared to the model based techniques. They are known to be much better, since, in these not only geometrical features are used but they are also combined with the spectral properties of shadow like color or brightness etc. These approaches have been widely used in literature since they are simple and easy to implement. As stated in [6], they can be broadly classified as: i) thresholding-based; ii) color-transformation-based; iii) region-growing-based; and iv) classification-based.

Reference [7] summarizes the categorization of shadow detection techniques given in [8] where moving cast shadow detection methods have been classified as: (i) color/spectrum-based methods; (ii) texture-based methods, and (iii) geometry-based methods. According to [9] moving shadows can be detected based on: *(i)* intensity information, *(ii)* photometric invariant information and *(iii)* color and statistical information. Also, in [10] shadow removal methods have been categorized as: *(i)* chromaticity-based methods; *(ii)* physical methods; *(iii)* geometrical-based methods and *(iv)* texture-based methods.

Various shadow detection methods have been listed along with their pros and cons in Table II.

TABLE II. AN OVERVIEW OF VARIOUS SHADOW DETECTION METHODS

SR NO.	METHOD	PRINCIPLE	PROS	CONS	RELATED WORK
1	**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.	Song et al. [6], Luus et al. [11], Kuo et al. [12]
2	**Texture based**	Takes in account the similarity between background and shadow texture as well as the difference in foreground and background textures	Accurate results under stable illumination conditions. Best for indoor scenes.	Difficult to implement. Poor performance for outdoor scenes as texture cannot be captured.	Golchin et al. [5], Leone et al. [13], Leone et al. [14], Heikkila et al. [15]
3	**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.	Requires a lot of computational time. Inaccurate for fine variations in images.	Xu et al. [16], Xu et al. [17]
4	**Classification 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.	Guo et al. [18], Liu et al.[19]
6	**Geometric Properties based**	Sets of geometric features are matched.	Effective detection under simulated and controlled environment.	Huge computation. Not feasible for spatial, real-time cases. Dependent on object-scene relationship.	Golchin et al. [5], Asaidi et al. [20]
7	**Color Based**	Spectral information is exploited. 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.	Golchin et al. [5], Chung et al. [21]

8	**Chromaticity 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.	Song et al. [6], Liu et al. [22], Shi et al. [23]
9	**Color and Statistical Information**	Probabilistic function from illumination model helps decide shadow and non-shadow pixels. **Types:** **Parametric:** Spatial and temporal information used. **Non-parametric:** Information derived from image only used.	Efficient shadow detection.	Poorly conditioned, high cost of computation.	Golchin et al. [5], Liu et al.[24], Kampel et al. [25]
10	**Partial Differential Equations**	Image smoothing is done via filters like convolution as in [26]. Gradient value is used for shadow detection.	Flexible, simple to implement, additional information other than image is not required.	Does not perform well on edges which span large gaps or holes [27].	Wang et al. [26]
11	**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.	Saves computation time.	Depends on synthetic training.	Golchin et al. [5], Yang et al. [28], Jacques et al. [29]
12	**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.	Sun et al. [30], Ma et al. [31], Sun et al. [32]

III. CONCLUSION

In this paper, a survey of various shadow detection techniques has been presented. The fundamentals of shadow and shadow formation have been discussed. Also, various shadow detection approaches have been summarized and compared by discussing their advantages and limitations. Shadow detection can be performed by either using the methods described above individually or in combination with one or more of the techniques mentioned in the table above.

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