Survey of Cast Shadow Detection Methods

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Abstract—Illumination conditions cause problems for many computer vision algorithms. Shadows in an image may lead to failure of segmentation, tracking, or recognition algorithms. Cast shadows always move with their corresponding objects such that background subtraction cannot separate them accurately. This might lead to object merging, object shape distortion, and object losses. Shadows should be identified and removed in order to provide a correct description of the objects. In this paper, different methods used to detect cast shadows are discussed.

I. INTRODUCTION

The performance of computer vision systems can be improved by shadow removal process. Shadow creates adverse effects on image analysis. Hence more attention must be paid to the area of shadow detection and removal. Shadow detection remains an extremely challenging problem, particularly from a single image. It is difficult to decompose a single image into shadow part and non shadow part.

Detecting and tracking of moving objects is required for many of the computer vision applications that deal with video. Shadow is a major concern that arises while dealing with the detection of objects in computer vision systems. Sometimes shadows are classified as part of the foreground. This happens because shadows share the same movement patterns and have a similar magnitude of intensity change as that of the foreground objects.

Shadow is a region of relative darkness. Shadow occurs when an object totally, or partially occludes direct light from a light source. Shadows can be classified as self shadows and cast shadows. Self shadow occurs on the object occluding the light. Cast shadow is the shadow generated by one object on some other objects. Cast shadows can be further divided into Umbra and Penumbra part. Umbra is the darkest part of shadow. Within umbra, light source is completely blocked by the object casting the shadow. Penumbra is the part where light source is partially blocked. Penumbra occurs only when light source is not a point source.

While detecting moving objects in video surveillance, cast shadow may also be classified as object where as self shadow does not causes that much of issues in video surveillance. For detection and removal of cast shadow many algorithms exists. In this paper, a survey is done based on different techniques used to detect and remove cast shadows.

II. LITERATURE SURVEY

The choice of features for the detection of shadow has more significance than the choice of algorithms. The features such as intensity, chromaticity, physical properties, geometry and texture are mainly used for the detection of shadows. The usefulness of these features and the work done in these corresponding fields are discussing here.

Yuan Zhou uses the intensity feature of the shadows [1]. To detect and remove mountainous shadows, he made use of the assumption that shadow regions are relatively darker than other regions. He applies water mask to eliminate the water bodies and segments the shadow regions based on their intensities. Neda Salamati proposes a new method [2] to remove the shadows that are detected when first applying foreground segmentation shadow detection method which is based on intensity. Here shadow regions are lighten up in order to obtain a shadow free image.

Thiago Statella proposed the application of mathematical morphology to detect shadows and clouds in a topographic surface image [3]. The method takes advantage of the fact that shadows are low intensity areas and clouds are high intensity areas of a topographic surface image. The method is highly sensitive to the presence of shadows.

The method proposed by Leone and Distante [4] creates a mask with the potential shadow pixels in the foreground. Then, if the textures of small region centred at each pixel are correlated to the background reference, the pixels are classified as shadow. Sanin et al [5] proposed using colour features to first create large candidate shadow regions, which are then discriminated from objects using gradient-based texture correlation. The texture for each candidate region is correlated between the frame and the background reference.

Shoaib et al presents a moving human cast shadow detection technique based on the texture information [6]. The algorithm is based on assumptions that shadows do not change the texture of the background and a cast shadow lies outside the boundary of an object with relatively small common boundary with the object.

K Emily Esther Rani and G Jemilda [8] introduced a pre-processing step using RGB colour model to identify the presence of shadows in an image. Once, the presence of shadow is confirmed then the image is converted into shadow invariant image. The algorithm describes the attenuation relationship between shadow and its non-shadow region.

Liu et al [9] detected shadow using pixel-level information, region-level information, and global-level information in HSV color space. Pixel-level information is extracted using GMM. Local-level information is used in two ways. First, if a pixel gets a sample that is likely to be a shadow, then not only the GMM of that pixel is updated but the GMM of neighbour pixels.

Saritha Murali and V K Govindan in [10] proposed a shadow detection and removal method using LAB colour space. The color space is converted from RGB to LAB color space. They assumed that the shadow regions are darker and less illuminated than the surroundings. So it is easy to locate them in the L channel since the L channel gives the lightness information. The B channel values in outdoor images are lesser in shadow areas. Thus combining the values from L and B channels, and then pixels with values less than a threshold is identified as shadow pixels.

With the knowledge of the illumination source, object shape, and the ground plane, the shadow's orientation, size and even shape can be predicted. The main advantage of geometry features is that they work directly in the input frame. Hence accurate estimation of background reference is not required. The method proposed by Hsieh et al [11] separates the foreground blobs into individual objects before doing the geometric analysis. They assume that the objects of interest are persons and their shadows have different orientation.

E Salvador, A Cavallaro and T Ebrahimi proposed an approach to detect and classify shadows for still images in [12]. They exploit invariant colour features to classify cast and self shadows. They perform edge detection along with morphological operations to extract cast shadow and the object part. Uniformed colored object and non structured surfaces are the constraints in this method. Subsequently, E Salvador, A Cavallaro, and T Ebrahimi proposed an approach using invariant color features [13] to segment cast shadows in both still and moving images. Motion detector will identify the moving areas and analysis will be perfomed in those areas.

Li Xu, Feihu Qi and Renjie Jiang proposed a comprehensive method [14] to remove vague and hard shadows from images. Initially they convert the input image to the logarithmic domain. To separate the vague shadows from a single image they used the derivative of the input image. This vague shadow edge detection is based on the assumption that vague shadows varies slowly across an image, but changes in materials are rapid.

Rosin et al [15] assumed that shadow is a region with reduced contrast and shadow region is detected using region growing algorithm. But the problem is that region growing algorithm cannot perform accurately in the penumbra part of the shadow.

In [16,17], a segmentation procedure recovers shadow regions with photometric gain smaller than unity and roughly constant (except at the edges). In particular, authors suggest a region growing algorithm that uses a growing criterion based on a fixed attenuation of photometric gain over the shadow region. Experiments have been accomplished in presence of pedestrians in outdoor environments. In these cases, a priori assumptions are made, so that the approach detects only shadows occupying a large area with respect to the object.

In [18], authors derive an invariant RGB shadow-free image on the assumptions that illumination varies slowly and small gradients in each frame are due to illumination, whereas large gradients depend on reflectance changes. Edges in the input image that do not appear in the invariant image are marked as shadow edges, so that a shadow-free image is evaluated by thresholding the gradients.

In [19] a multi-gradient analysis is applied to the division image between the smoothed image and the reference background. Edge matching is performed on each blob's boundary and allows discarding regions which are too far from the boundary (or too small). The approach shows good results when attached shadows have been presented.

Brightness/chromaticity distortion model is evaluated in [20, 21] where a pixel is classified as shaded background or shadow if presents similar chromaticity but lower brightness with respect to the corresponding background pixel. The method may suffer from dynamic scene changes, especially for reflection on highly specular surfaces.

The adoption of hue/saturation/value information and the ratio between image and corresponding background luminance improve shadow detection [22, 23]. The empirical choice of several threshold values deters the use of the scheme, forcing the system to tune up parameters every time the context changes.

In [24], authors extract penumbras and self/cast shadows using a three-level approach. The first detects dark regions, the second extracts vertexes and gradients in dark regions and the last integrates these features confirming the consistency along the light directions. The drawback is the estimation of the source light position. Cavallaro et al. [25] use color invariants, spatio-temporal constraints and photometric invariant features without knowledge of objects. The selective use of photometric invariants improves the performance in the shadows removing approach.

In [26] authors detect penumbra and shadows using a two adjacent frame difference approach. A linear luminance edge model is applied to detect shadow boundaries. A Sobel operator is measured perpendicularly to the borders and the result are thresholded using the gradient outcome and the edge model. Moreover, the ratio between adjacent frames is thresholded on the local variance. Results show restricted indoor environments and only one moving person. The algorithm should be adjusted to work on outdoor scenes as well.

In [27], a Gaussian shadow modelling is proposed. The method uses the vertical edges information for the segmentation and a histogram-based approach to discriminate pedestrians. A moment-based method is performed to obtain the rough shadow boundaries, so that shadow regions can be refined using a Gaussian shadow model, choosing appropriate parameters (orientation, mean intensity and centre position of the shadow).

A physics-based shadow detection approach is proposed in [28], making no assumptions about geometry of the scene but requiring a static background. This method performs a segmentation based on blue-ratio and spatio-temporal albedo test, using a dichromatic reflection model. Researchers assume the presence of people in the scene, whereas shadow regions are only illuminated by the sky. Performances are affected by background colour saturation.

As concluded in [29], many methods need ad hoc studies according to different kind of scenes and their use is restricted to specific environments. Moreover, the two most relevant problems are the tuning of the shadow identification system (the definition of the most appropriate thresholds or constraints) and the characterization of features used for shadow detection. Shadow areas are lesser illuminated than the surroundings. F i n l a y s o n, H o r d l e y and D r e w [30] proposed a method to locate the shadows by generating an illumination-invariant image, in which the shadows do not appear. The illumination-invariant image is used with the original colour image to locate the shadow edges. These edges are set to zero and the edge representation is reintegrated to get the shadow-free image.

Removal of shadows using multiple Retinex paths was proposed in [31]. Reintegration by solving Poisson equation and using a large number of random paths in retinex method are both computationally expensive. A faster method for shadow removal by averaging the results of reintegration along a few numbers of Hamiltonian paths in the image was proposed in [32]. F r e - d e m b a c h and F i n l a y s o n [33] proved that the error propagation during reintegration can be reduced by closing the shadow edges before reintegration. Reintegration is done along Hamiltonian paths in the image that enters and leaves the shadow region only once.

In [34] the shadow removal is achieved in three stages. A 1D shadow-free illumination invariant image is created. From this, a 2D color representation is derived and then a 3D shadow-free color image is generated. The shadow edges are finally corrected by inpainting. F r e d e m b a c h and F i n l a y s o n [35] suggested that the shadow regions differ from the non-shadow representation by a single constant which can be calculated in a little time. The constant for R, G and B channels are calculated separately. The constant is such that the addition of the shadow region with the constant will reduce the difference between the shadow region and the surroundings.

X u, Q I, and J i a n g [36] proposed a method to detect vague shadows in a image using derivatives of the input image. The hard shadows are detected using colour invariant image. A shadow-free image is reconstructed by reintegration using Poisson equation. A method to remove the shadows from curved areas retaining the background texture is proposed in [37]. The removal of shadows is achieved by calculating different scale factors for shadow regions and penumbra regions to cancel the effect of shadows.

F i n l a y s o n, D r e w, and L u [38] proposed that the shadows can be removed by minimizing entropy. The distribution of pixels with less entropy can be achieved by taking 1D projection in the correct invariant direction. The detection of shadows is more complicated in the case of monochromatic images, than colour images. An approach to extract shadows from an image using the information supplied by the user is proposed in [39]. The image is segmented and the shadow, non-shadow and background regions are interactively specified by the user. The shadow removal is achieved by graph cut algorithm.

Z h u et al. [40] proposed a method to detect the shadows in single monochromatic image using shadow invariant, shadow variant and near-black features. In [41], trained decision tree classifier is used to detect the shadow edges in outdoor images. The shadow edges are then grouped by a Conditional Random Field (CRF) based optimization. A region-based approach to detect and remove the shadows from an image was proposed by G u o, D a i, and H o i e m [42]. 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.

A method to detect the shadows in a single image using a Tricolour Attenuation Model (TAM) was proposed in [43]. The shadow identification is done followed by generation of an invariant image on which segmentation is performed. TAM is then used to detect the shadow. But the dark areas are misclassified as shadows. S a l v a d o r, C a v a l l a r o, and E b r a h i m i [44] proposed a method to identify and classify the shadows in colour images. Luminance and colour information are used to detect shadows. This method also classifies the shadows as self or cast shadows. But restrictions are placed on the light source for the method to work efficiently. In [45] the shadow removal is done by illuminating the shadow region till it gets the same illumination as the surroundings. The texture is retained. The shadow removal is done using energy function in [46], assuming that the lighting needed in the shadow region is a constant.

III. CONCLUSION

Shadows can be detected using several features such as intensity, chromaticity, texture and geometry. The methods using these features have some advantages and disadvantages. Methods using intensity alone are easy to detect shadows but are much prune for noise. As like intensity methods, chromaticity method is also susceptible to noise. Texture based methods better detect shadows but need a lot of pre-processing steps. Geometry based methods are best to remove the shadows if constraints based on shape of objects can be applied. The method that uses multiple features in a parallel way will better detect the shadow region.

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