A Survey on Various Shadow Detection Methods

Siddhi Shah¹, Nikunj Gamit²

¹M.Tech Student, Computer Engineering, Chhotubhai Gopalbhai Patel Institute of Technology, Bardoli, India
²Assistant Professor, Department of Computer Engineering, Chhotubhai Gopalbhai Patel Institute of Technology, Bardoli, India

Abstract—Shadows appear in many scenes. Shadows in images are typically affected by several phenomena in the scene, such as lighting conditions, type and behavior of shadowed surfaces, occluding objects etc. One of the core issues is to detect the shadow accurately. Accurate shadow detection can be difficult due to the illumination variations of the background and similarity between appearance of the objects and the background. There have been numerous researches done on shadow detection to address the challenges. Many algorithms and methods have been developed for different environmental conditions to detect shadow from the images. This paper reviews some methods to detect shadows and analyzes their correctness. This paper is aimed to provide a survey on various algorithms and methods of shadow detection with their comparative study and advantages and disadvantages.

Keywords—Image Processing, Shadow, Shadow Detection, Detection Algorithm, Segmentation, Color Information.

I. INTRODUCTION

Image processing has been one area of research that attracts the interest of wide variety of researchers. Image processing mainly 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.

For example, image segmentation methods often cannot resolve two separate objects because of a shadow cast in between them and tend to detect the two objects as one object [3]. It reduces the reliability of many computer vision algorithms like segmentation, object tracking, scene analysis, classification of objects, etc. 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 pre-processing step for improving performance of such computer vision algorithm and image enhancement [6].

II. OVERVIEW OF SHADOW

A. Shadow

A shadow occurs when an object partially or totally occludes direct light from a source of illumination. 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.

B. Self and Cast Shadow

Shadow can be classified into two groups: cast shadow and self shadow. Cast shadow is caused by the projection of the light source in the direction of the object. Self shadow is still a shadow but represents the part of the object that is not illuminated directly by the light source. 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 [1].

Figure 1: Different types of shadow [7]
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-shadow usually have a higher brightness than cast shadows since they receive more secondary lighting from surrounding illuminated objects [4].

C. Properties of Shadow

There are some properties extracted from images which can be used to distinguish between an object, the background and shadow [3]. These properties are listed as following.

- A shadow has a lower brightness (illumination) in comparison to the background pixels and this difference changes smoothly between neighboring pixels.

- All Red-Green-Blue (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 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. Natural images often contain shadows and these usually confound their analysis by current computer vision approaches. It has been found to be difficult to distinguish between shadow and non-shadow regions when they have similar hue, saturation and intensity. We have referred some approaches of shadow detection in various scenarios.

III. SHADOW DETECTION APPROACHES

A. Based on Intensity Information

A comparative study on the shadow detection methods [8], based on Intensity information, based on photometric invariants information, and color and statistical information method, gray-scale pixel intensity value in the presence of illumination changes fails to detect shadow region accurately. Actually the pixel intensity value is susceptible to illumination changes.

B. Based on Texture Information

Texture based methods rely on the fact that regions under shadow keep most of their texture. These algorithms vary a lot in implementation but in general they follow the same basic steps: selection of candidate shadow regions and classification of these regions as shadow or foreground based on the texture correlation between frame and background. However, various implementations use different sizes of regions to correlate textures and also different correlation techniques. Texture based methods offer great potential since textures are very characteristic, robust to illumination changes, and independent of colors. However, they are typically computationally heavy.

C. Shadow detection using Segmentation

In the detection process shadow and non shadow regions are separate by SVM classifier [2]. This classification procedure is used to implement in a supervised way by means of a support vector machine (SVM), which showed the effectiveness in data classification. The classification task is performed to extract the features of the original image with the help of wavelet transform. Initial level wavelet transform is applied on each spectral band which consists of frequency features. Morphological filters are introduced to deal with the problems occurred and to improve the quality by their effectiveness and to increase the capability in the shape preservation is performed by the possibility to adapt them according to the image filtering techniques (extracting the borders and shape of the surface) [2].

D. Shadow Detection using Mask Construction

In this method, shadow image is considered in RGB color space. Mask value will be automatically calculated to grayscale image. Structuring element (SE) to burr the shadow mask is considered. M. S. V. Jyothirmai et al. [4] takes structuring element SE 5x5 array of 0s or 1s. Initially this is 3x3 array in existing approaches which yields blurred edges and producing more light to shadowed pixels.
To overcome the problem they conduct no. of experiments on shadow mask values and finally conclude SE as 5x5 array. This method is easy to implement as it directly uses RGB color space without any Laplacian or gradient transforms of image. It accurately detect the shadow area in satellite images. It detect the shadow area when texture color and shadow color is different. But it cannot give accurate shadow detection when background texture or object is similar to the color of shadow area.

E. Shadow Detection Using Color Information

To detect shadow pixels using the color information, first the Hue-Saturation-Intensity (HSI) color space, extended gradual C1C2C3 color space, YCbCr (Luminance, Chroma Blue, Chroma Red) color space and LAB color space. These color features are selected due to their remarkable difference between the shadows, background and object pixels. The shadow pixels based on each of these calculated features are detected separately. Then the results are combined using a Boolean operator (logical AND) to construct the shadow image based on the color information [3]. Color spaces represent colors with different vector values. One of the most common examples is the RGB space where a pixel has three values which represent the amount of red, green and blue. These three values span a color space that can represent most of the colors that can be detected with the human eye [3].

F. Shadow Detection Using the Edge Information

Edge detection is one of the most commonly used operations in image analysis, and there are probably more algorithms in the literature for enhancing and detecting edges than any other single subject. Computer vision involves the identification and classification of object and shadows in an image, edge detections is an essential tool.

After converting the RGB color image into the HSI color space, the extended gradual C1C2C3 and the YCbCr color space, rough shadow-detected pixels are achieved using these color information. But there are still misclassified pixels. To detect missing pixels edge information is used [3]. There are various edge detection techniques i.e. Canny, Laplace, Prewitt, Sobel edge detection. Basically edge detection techniques identify points in a digital image where brightness changes sharply or has discontinuity.

The comparative analysis of these methods are shown in table 1.

Table 1: Comparative Analysis of Various Shadow Detection Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Principle</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on Intensity</td>
<td>Standard deviation is calculated for ratio value. Conditions are set</td>
<td>Function for pixel intensity is estimated directly from the data without any other assumptions</td>
<td>Actually the pixel intensity value is easily affected to illumination changes.</td>
</tr>
<tr>
<td></td>
<td>for a shadowed pixel.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texture based</td>
<td>Takes in account the similarity between background and shadow texture as</td>
<td>Best for indoor scenes.</td>
<td>Difficult to implement. Poor performance for outdoor scenes as texture capturing is difficult.</td>
</tr>
<tr>
<td></td>
<td>well as the difference in foreground and background textures.</td>
<td></td>
<td></td>
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<tr>
<td>Segmentation</td>
<td>Classification techniques like SVM are used based on the properties</td>
<td>Can detect probable shadow boundaries accurately. Simple and easy to implement.</td>
<td>There are chances of misclassification. Shadows of small objects are missed sometimes.</td>
</tr>
<tr>
<td></td>
<td>possessed by shadow pixels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mask Construc</td>
<td>Binary shadow Mask is computed. It uses Structuring Element.</td>
<td></td>
<td></td>
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<tr>
<td>tion based</td>
<td></td>
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<tr>
<td>Color Based</td>
<td>Color tune value of shadow and background same but different intensity.</td>
<td>Gives accurate Result for satellite images. It can correctly separate shadow and non-shadow</td>
<td>Fails when intensity of shadow and background is same.</td>
</tr>
<tr>
<td></td>
<td>Color differences of shadowed pixel and background pixels as well as</td>
<td>regions. Computationally Inexpensive. Performance for outdoor scenes is better.</td>
<td></td>
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<tr>
<td></td>
<td>illumination invariance are used.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge Based</td>
<td>It used when brightness changes sharply or has discontinuity and to detect</td>
<td>An edge gives the boundary between shadow and the background.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>missing pixels.</td>
<td></td>
<td>It is not suitable for small objects and their shadows.</td>
</tr>
</tbody>
</table>
IV. METRICS OF PERFORMANCE EVALUATION

In order to analyze the different shadow detection methods, the shadow detection rate \( \eta \) and shadow discrimination rate \( \zeta \) are widely used [3]. They are defined as follows.

\[
\eta = \frac{TP_S}{TP_S + FN_S} \quad (1)
\]

\[
\zeta = \frac{TP_F}{TP_F + FN_F} \quad (2)
\]

In equation 1 and 2, the subscript symbol S stands for shadow and F for foreground, where \( TP_S \) and \( TP_F \) respectively represent the numbers of shadow pixels and foreground pixels correctly recognized. \( FN_S \) and \( FN_F \) respectively represent the numbers of shadow pixels and foreground pixels falsely recognized.

V. CONCLUSION

In this paper, first the basics of the shadow, how shadow occurs, then different types of shadows are mentioned which appear in the images. Secondly, we have provided a comprehensive survey of shadow detection methods in indoor outdoor scene, traffic surveillance images etc. Paper presents comparative analysis of different methods for different types of images.

REFERENCES


