Moving Object's Cast Shadow Removal

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Abstract

Moving object's cast shadow removal is the active and challenging research area in computer vision and digital image processing. Removing cast shadow is the primary step for object tracking and segmentation system. Shadow cause false classification and shape distortion. So, the system is proposed to remove the moving object's cast shadow in the outdoor environment. In the system, background modeling is initially performed by averaging the movement regions. After background modeling, foreground objects are extracted using the background subtraction method. Frame normalization, V channel of HSV color space, Otsu thresholding approach, morphological processing and region properties are employed to detect the cast shadow region. After shadow detection, the shadow is removed based on previous background model. Experimental results show the proposed method can detect and remove cast shadow region properly.

***Keywords**: background modeling, normalization, HSV color space, region properties, morphological operation*

1. Introduction

Shadow detection and removal is an interested preprocessing step in tracking, counting and recognition systems. In image processing, shadow is a region where direct light from a light source can't be reached. On the other hand, shadow is a dark region of an object. There are two kinds of shadows: self-shadow and cast-shadow, also called soft and hard shadow respectively. Self-shadow occurs on the objects occluding the direct light from a light source and cast-shadow appears on the ground that is generated by the object. Self and cast shadows have different quantity of light value. Self-shadows have higher brightness than cast-shadows. Self-shadows can't give any problems for detection and recognition systems. Although self-shadow can't affect the surface texture, cast-shadow cause a loss of surface texture. Cast shadows can be misclassified as foreground objects as their pixels are the same as the foreground pixels. Moreover, shadows can also change the shape and size of objects in detection system. Tracking results may be inaccurate because they move along with the moving objects. Almost tracking and detection system can't solve the shadow problems. Hence, a simple method is proposed to detect and remove cast shadow region.

The rest of the paper is organized as follows. Section 2 lists the related work. Section 3 presents the proposed shadow detection and removal method. In section 4, experimental results are described. Finally, section 5 outlines the conclusion and future work.

2. Related Work

In recent years, moving cast shadow detection and removal has made great significant progress. Different shadow detection and removal techniques [9] are carried out. Shadow detection methods can be classified by following their features [5, 7]. They are (i) color based techniques, (ii) texture based techniques, (iii) statistical based techniques, (iv) geometrical based techniques, (v) grey-scale based techniques, and (vi) image based techniques.

An approach based on gamma decoding is suggested by Mohamed et al. [10]. The authors recommend a method that employs the estimated background model of the video sequence and applies a Gamma decoding followed by thresholding operation. However, it fails for lowest pixels range for cast shadow region. The method of [12] is based on texture information in which shadow regions remain the same texture as the corresponding background regions. Although texture based method can adapt to variant illumination, their processing time tend to be slow since their computation are expensive and not efficient for texture less conditions. Maryam et al. [7] suggested a shadow detection method using both color and edge information. In this work, a new formula is used in the denominator of original c1 c2 c3. And then, edge information is applied separately and the results are combined using a Boolean operator. But, this becomes a problem when the difference of color information between object, shadow and background is poor, and the edge of the shadow area is not clear. In the proposed method of Xinbo et al. [8], multi-frame average method is presented. However it is unavailable for removing the shadow from the slowly moving objective. Tomasz Kryjak presents a shadow detection and elimination algorithm designed for greyscale video sequences [6]. The author recommends an automatic method for determining the binarization threshold on the basis of the object edge analysis, division of areas identified as potential shadow using a rectangular grid, analyzing the similarities between the current frame and the background model and analyzing the potential shadows areas position relative to the position of areas identified as a true object. However, color information is not always available since black and white cameras are more sensitive in low illumination conditions and have a higher resolution.

3. Proposed Method

In object tracking systems, moving shadow detection is the important issue for performance measurement. Moreover, shadows are also main cause of background texture loss and false connectivity. Hence, a simple method is proposed to detect the object's cast shadow region and remove that detected shadow region from video frames. The overview of the proposed framework is shown in figure 1.

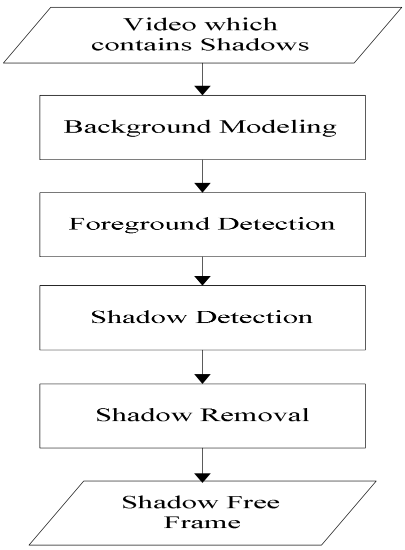

Figure 1. System Overview

3.1. Background Modeling

In moving shadow detection and removal systems, background modeling is the important and primary step. It is also essential step for foreground detection. Actually, background modeling is the background pixel estimation [4]. An excellent background model can give the good foreground detection results. There are two kinds of background modeling [1]:

- Non-statistical approaches and
- Statistical approaches.

In non-statistical approaches, background image is usually extracted from the initial frame, i.e. the first frame is considered as the background. In the later group, the statistical based approaches, the likelihood that a pixel belongs to the background is computed. Although non-statistical approach is fast, statistical approach can give better performance than the other one.

The proposed background modeling method use averaging the movement regions in a video to get the minimum effect of moving objects in the calculation.

3.1.1. Step By Step Process of Background Modeling

Step 1: The input is the video contains shadows.

Step 2: First Iteration,

- Define sample number for frame averaging.
- Initialize zero to extracted frame.
- Add next preceding frames to the extracted frame.
- Find total number of pixels.
- Calculate frame averaging.

Step 3: Second Iteration,

- Find absolute difference between frame averaging and extracted frame.
- Find pixel sample density. Use (1) to find pixel sample density.

$$PSD \mathrel{+}= Absolute\ Difference \quad (1)$$

where PSD is the Pixel Sample Density.

- Find non-moving regions. Use (2) to find non-moving regions.

$$NMR = Extracted\ Frame * Absolute\ Difference \quad (2)$$

where NMR is the Nonmoving Region.

- Add non-moving regions to the extracted frame.

Step 4: Find background frame by dividing the extracted frame with pixel sample density.

First, extract frame from input video that contains shadows. And set that frame as background frame initializing the zero value. After initializing the background frame, add the next preceding frames to the background frame. And then the averaging is performed, i.e., divide total number of pixels by number of existing frames. After averaging, the first step in background manipulation is finished.

However, to get the clear and precise background, the second step must be performed. Therefore find absolute frame difference to get the non-moving regions and pixel sample density. And then add the non-moving regions to the background frame. Finally, the background frame is divided by pixel sample density to obtain the clear background frame. This background modeling method can remove the foreground objects very accurately.

3.2. Foreground Detection

After background modeling step, foreground objects must be extracted. Foreground detection is also one of the main tasks for moving cast shadow detection. Foreground detection is the foreground object's extraction. Some applications don't need every movement in the video. They require only the changing pixel information. In such cases, only moving foreground objects need to be extracted.

In this proposed system, foreground is detected using the background subtraction method. To detect the moving objects in video frames, background modeling must be constructed initially. Then the extracted current frame is subtracted from the background model. The difference between the extracted current frame and the background frame determines the moving objects. The detailed flow for foreground binary mask manipulation is shown in figure 2.

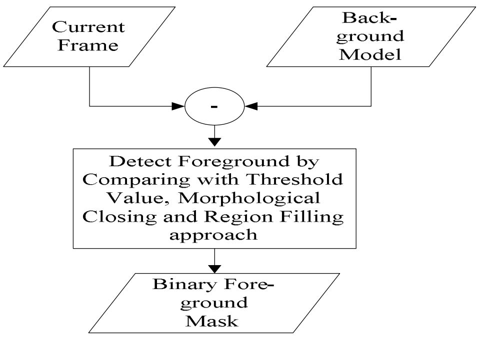

Figure 2. Foreground Detection using Background Subtraction Method

In foreground detection step, the current frame extracted from the input video and the background model from the previous section is used as inputs in order to detect the foreground objects. And subtraction operation [2] is performed, i.e. subtract current frame from the background frame. After subtraction, the result is compared with threshold value. Threshold is put on this difference image to improve the subtraction. Result less than threshold is considered as foreground objects. After comparing with threshold value, morphological closing and region filling approach are used to get the clean and distinct binary foreground mask. This subtraction method is very simple and robust. In image processing, closing removes small holes and region filling fills holes in the input binary image.

3.3. Shadow Detection

After background and foreground modeling, shadow region can be detected based on the HSV color space. Shadow detection is the process of detecting object's shadow region and shadow removal is the process of removing detected cast shadow region. Shadow can cause embarrassment and unreliable in object tracking and detection systems. Moreover image visual quality can also be degraded. Shadow detection and removal is an important preprocessing step in the surveillance systems. The flowchart of the proposed method for shadow detection is shown in figure 3.

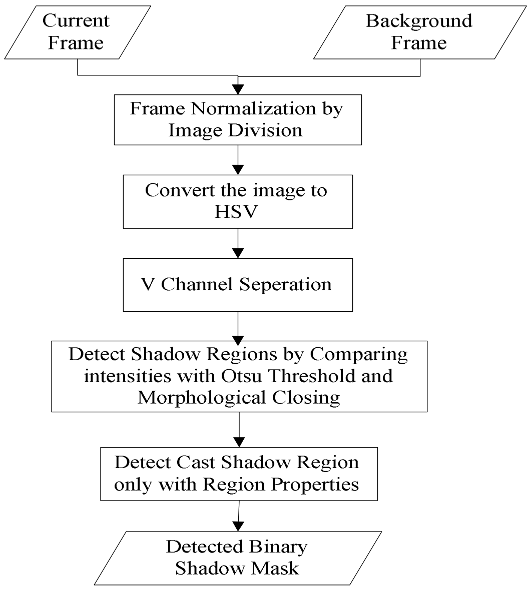

Figure 3. Flowchart of the Proposed Framework for Shadow Detection

In the step of shadow detection, the current frame and the background image from the previous section are used as inputs in order to detect the shadow region. And normalize the frame to find the homogeneous parts of the image, i.e. image division. This is also called Region of Interest (ROI). After finding ROI, convert the divided image into HSV color space. And then V channel is separated to concentrate on shadow region. Next, compute dynamic threshold value using Otsu method and compare the intensities with the threshold value. And then noises are removed using region properties. Finally the output is the binary shadow mask only.

3.3.1. Frame Normalization

Frame normalization is initially performed for shadow detection. Normalization is a process of changing the range of pixel intensity values. The basic idea of the frame normalization is to highlight the homogeneous part of shadow region [11]. Frame normalization is the division of foreground model and background model.

3.3.2. HSV Color Model

In shadow detection, the previous divided image is converted to the HSV color space because HSV color space is the best color space to distinguish shadow from objects.

HSV color space separates color into three components, hue, saturation, and value. H is Hue, S is Saturation and V is Value. HSV color is not the primary color model. Hue and saturation taken together are called chromaticity. The V channel represents the intensity or brightness. Therefore a color may be characterized by its brightness and chromaticity.

Unlike RGB, HSV color space is a uniform color space. RGB is not conducive to the color image segmentation. HSV color space is not only show how the human eye visual observation the color, but also suitable for image processing. The main advantage of HSV color model is giving clear image segmentation [3]. Although many methods works on RGB and YCbCr color models, the proposed system applies HSV color space to detect the cast shadow region. Intensity in V channel of HSV color space is separated to detect the shadow region.

3.3.3. Thresholding with Otsu's Algorithm

When the image is converted of HSV color space and V channel separation, segmentation approach must be performed.

Thresholding is the process of segmentation of an image, i.e. separation of light and dark regions. Otsu's method is a global thresholding technique. It's entirely based on histogram computation. The basic idea is that a threshold value giving the best separation between classes in terms of their intensity values would be the optimum threshold. The optimum threshold can be obtained by maximizing the between-class variance. Therefore, the goal of Otsu's algorithm is to find the between-class variance.

3.3.4. Region Properties

When detecting shadow region using Otsu's Algorithm, some other noise are also contained. Therefore, that unwanted noises are removed by using region properties. Initially, region boundaries calculation must be performed. Region boundaries calculation traces the exterior boundaries of objects, as well as boundaries of holes inside these objects. After region boundaries detection, label matrix where objects and holes are labeled must be maintained to remove the unwanted noise. Finally, only cast shadow regions can be detected by removing the other noise regions using region properties.

3.4. Shadow Removal

After shadow detection, the detected shadow region must be removed. A fast and simple method for removing shadow is proposed. A flowchart of the proposed framework for shadow removal is shown in figure 4.

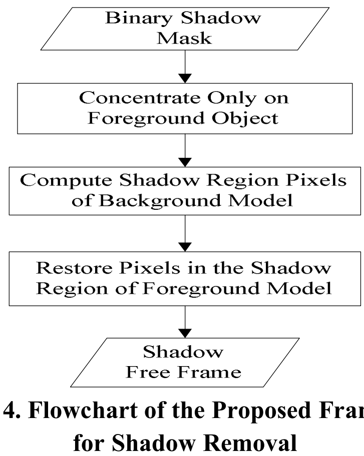

Figure 4. Flowchart of the Proposed Framework for Shadow Removal

For removing shadow region, the binary shadow mask from previous section is taken as input. The main purpose of using the foreground binary image is to work with the operations only in the region of the moving object. The pixel values of the shadow region in background model are computed. These pixel values are placed over the shadowed part of the foreground model to obtain the shadow free frame.

4. Experimental Results

In this section, several experiments were conducted on several video clips that contain different background, different color objects and different light source. As there is no typical dataset, variety of videos are chosen: CCTV videos, captured video clips which consists of shadow. This system is implemented with MATLAB (R2016a).

In this experiment, three short video clips (AVI format): CCTV1, CCTV2 and Video1 are selected to test the proposed method. The extracted frame number for CCTV1 and CCTV2 are 36 and 77 respectively. CCTV1 and CCTV2 are provided by traffic sample site. For both CCTV1 and CCTV2, frame resolution is 240x320, scene type is outdoor, object type is vehicle and the sizes of object and shadow are large. In the testing of Video1, the extracted frame number is 19. And frame resolution is 240x432. It is captured by phone camera in outside. The object type is human, object size is large and shadow size is small. The testing results of CCTV1, CCTV2 and Video1 are shown vertically in figure 5 by applying the proposed method.

CCTV1 **CCTV2** **Video1**

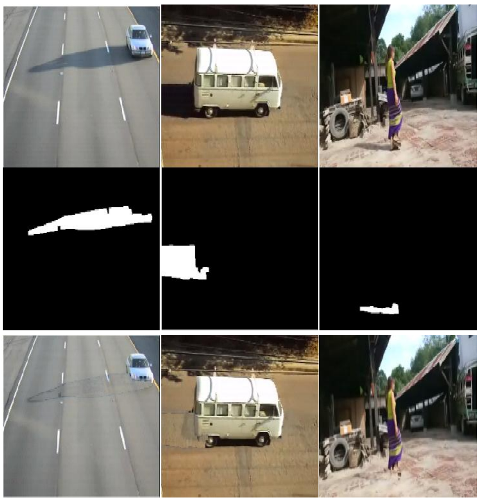

Figure 5. The Results of Applying the Proposed Method on Different Video Sequences: Original Frame, Shadow Detection Result, Shadow Removal Result, Respectively

The accuracy of shadow detection and discrimination can be calculated by using (3) and (4) respectively.

$$\text{Shadow Detection Accuracy} = TP_s / (TP_s + FN_s) \quad (3)$$

$$\text{Shadow Discrimination Accuracy} = TP_f / (TP_f + FN_f) \quad (4)$$

where, TP_s is the number of pixels which are determined correctly as shadow pixels. FN_s is the number of errors in which shadow pixel is determined as object pixel. TP_f is the number of pixels which are determined correctly as foreground object pixels. FN_f is the number of false detection which defined object pixel as shadow pixel. Accuracy of shadow detection is shown in Table 1. Shadow discrimination accuracy in percentage is displayed in Table 2.

Table 1. Experimental Results of Shadow Detection Rate

Testing Video Clips	Number of ROI Pixels for Shadow	TP_s	FN_s	Shadow Detection Accuracy (%)
CCTV1	5241	4955	286	95%
CCTV2	3855	3720	135	96%
Video1	1046	923	123	88%
Overall	10142	9598	544	93%

Table 2. Experimental Results of Shadow Discrimination Rate

Testing Video Clips	Number of ROI Pixels for Fore-ground	TP_f	FN_f	Shadow Dis-crimina-tion Accuracy (%)
CCTV1	1916	1477	439	77%
CCTV2	17245	16955	290	98%
Video1	4979	4579	400	92%
Overall	24140	23011	1129	89%

The overall accuracy of the shadow detection rate is 93% and the shadow discrimination rate is 89% of the proposed system.

A contrast between the proposed method and other well-reported methods is displayed in Table 3.

Table 3. Comparison of Shadow Detection and Discrimination Rate

Method	Shadow Detection Rate (%)	Shadow Discrimination Rate (%)
Gamma Decoding Method [10]	91%	88%
Edge Method [7]	70%	86%
The Proposed Method	93%	89%

5. Conclusion

Removing dark cast shadow region is an unavoidable step in object tracking and recognition systems. Shadow removal leads to better tracking performance. Shadow detection and removal plays a vital role in digital image processing and computer vision system. In this paper, the system is proposed to detect a moving object's cast shadow and remove the shadow region from video frames. In the system, background modeling is initially performed. In order to extract the moving objects, background subtraction algorithm is employed. Frame normalization is calculated based on image division approach. Intensity in V channel of HSV color space, Otsu thresholding and region properties are used to detect the shadow region. Finally shadow removal is performed based on the information from the previous background frame. The proposed method can detect and remove shadow very well. Cast shadow detection for multi-objects and improving shadow removal are implemented as for future work.

References

[1]. G. Gordon, T. Darrell, M. Harville, J. Woodfill, "Background estimation and removal based on range and color", IEEE Computer Society Conference on Computer Vision and Pattern Recognition, June 1999.

[2]. Daniel Grest, Jan-Michael Frahm, and Reinhard Koch, "A Color Similarity Measure for Robust Shadow Removal in Real-Time", Germany, 2003.

[3]. Fadhlan Hafiz, Othman Khalifa, A. A. Shafie, M.H. Ali, "Foreground Segmentation-Based Human Detection With Shadow Removal", International Conference on Computer and Communication Engineering, ICCCE, Kuala Lumpur, Malaysia, May 2010.

[4]. Alexander Farley, "Background Modeling with movement region averaging", utoronto.ca, September 16, 2011.

[5]. Andres Sanin, Conrad Sanderson, Brian C. Lovell., "Shadow detection: A survey and comparative evaluation of recent methods", 4 April 2013.

[6]. Tomasz Kryjak, "Shadow Removal for Gray Scale Video Sequences", Image Processing & Communication, vol. 17, no. 4, pp. 117-130 DOI: 10.2478/v10248-012-0037-8, 18 April 2013.

[7]. Maryam Golchin, Fatimah Khalid, Lili Nurliana Abdullah and Seyed Hashem Davarpanah, "Shadow Detection using Color and Edge Information", Journal of Computer Science 9 (11): 1575-1588, 2013

[8]. Xinbo Zhang, Kunpeng Liu, Xiaoling Wang, Changhong Yu, Taozhang, "Moving Shadow Removal Algorithm Based on HSV Color Space", TELKOMNIKA Indonesian Journal of Electrical Engineering Vol.12, No.4, April 2014.

[9]. Gayatri Gurav, IIProf. M.B Limkar, IIIProf. Sanjay M. Hundiwale, "Study of Different Shadow Detection and Removal Algorithm", International Journal of Research in Electronics and Communication Technology (IJRECT 2014), Vol. 1, Issue 2 April - June 2014.

[10]. Mohamed Taha, Hala H. Zayed, M. E. Khalifa and Taymoor Nazmy, "Moving Shadow Removal for Multi-Objects Tracking in Outdoor Environments",International Journal of Computer Applications (0975–8887) Volume 97– No.10, July 2014.

[11]. Kaushik Deb, Animesh Kar, and Ashraful Huq Suny, "Cast Shadow Detection and Removal of Moving Objects from Video Based on HSV Color Space", Smart Computing Review, vol. 5, no. 1, February 2015.

[12]. Mani Ranjbar, Shohreh Kasaei , "Moving Cast Shadow Detection Using Texture Information", Department of Computer Engineering, Sharif University of Technology, 2017.