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Object's Shadow Removal with Removal Validation

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Abstract- *We introduce in this paper, a shadow detection and removal method for moving objects especially for humans and vehicles. An effective method is presented for detecting and removing shadows from foreground figures. We assume that the foreground figures have been extracted from the input image by some background subtraction method. A figure may contain only one moving object with or without shadow. The homogeneity property of shadows is explored in a novel way for shadow detection and image division technique is used. The process is followed by filtering, removal, boundary removal and removal validation.*

Keywords — Shadow removal, homogeneity, umbra, penumbra

I. INTRODUCTION

Shadow is a common problem that one could encounter in motion estimation of daytime traffic scenes. Shadows can cause object merging, object shape distortion etc., causing error in object tracking and classification. Many researchers had proposed shadow detection or removal based on priori information, such as the geometry of the scene or the moving objects and the location of the light source while others are based on shadow attributes. There are three main shadow attributes, firstly, shadows or moving shadows are attached to their respective obstruction object for most of the time, secondly, transparency which is that shadow always makes the region it covers darker and lastly, homogeneity which is the ratio between pixels when illuminated and the same pixels under shadows can be roughly linear.

Method that has been proposed in [1], [2], [3] and [4] is an image division technique (*between background and foreground*). Image division is used because it highlights the homogeneity property or attributes of shadow. For [2], after the image division process, a multi-gradient (*horizontal, vertical and diagonal edges*) operation is performed on the resultant image to remove penumbra region and for [3], edge gradient operation is applied after the division process to decide the shadow's blob. For [1], after the image division process, adaptive thresholding process is used to remove the umbra region and projection histogram analysis is applied to the resultant image to remove the penumbra region. In [4], global thresholding process is applied to the resultant image (*after image division*) in order to get the shadow's blob. The authors claim their method to be more generic in detecting and removing shadows.

The shadow detection method developed by [5] is applied to gray level images taken by a stationary camera. The authors used the Canny edge detector to both the foreground and background figures (*is mapped to the foreground's shape*). After that, image subtraction is performed on the foreground edges and background edges to extract the object's edges. Object recovery process is applied to the object's edges to recover object shapes on the basis of the information in the object's edges and attributes of shadow. There are three rules or attributes of shadow as defined by authors. Firstly, bright foreground pixels is preserved because they are impossible to belong to shadows. Secondly, foreground pixels with attributes different from the attributes of shadow are preserved and lastly, foreground pixels nearby object edges are preserved.

The approach described in [6] is applied for human or pedestrian and it is based on priori information which is object moment and object orientation. In order to precisely remove the unwanted shadows, this paper presents a histogram projection method to separate each pedestrian from moving region first. Then, a coarse-to-fine approach is applied for detecting the boundaries between the pedestrian and its shadow. At the coarse stage, a moment-based method is applied to estimate the orientation of the detected pedestrian. According to the orientation and silhouette features of the detected regions, a rough approximation of the exact shadow area can be detected. At the fine stage, the rough approximation of the shadow region is further refined through Gaussian shadow modeling. The major difficulty in shadow modeling is the choice of the proper model, which can reflect various appearances of shadows at different orientation and lighting.

The algorithm explained in [7] is almost similar to [6] and it is also based on priori information plus a little bit of shadow attributes. The authors try to locate object-shadow boundary in order to detect the shadow. This was done by creating one or more straight lines to approximate the boundary between vehicles and their associated shadows. These lines are located in the image by exploiting both local information (*e.g. statistics in intensity differences*) and global information (*e.g. principal edge directions*). The authors said this method does not assume a particular lighting condition, and required no human interaction or parameter training. Experiments on practical real-world traffic video sequences demonstrate that this method is simple, robust and efficient under traffic scenes with different lighting condition.

II. MOTIVATION

Many techniques which are based on homogeneity property of shadows assume that ratio between pixels when illuminated and that are when subjected to shadow is constant. But, authors in [1] said that the ground truth data show that the ratio is highly dependent on illumination in the scene and hence shadow detection will not be effective in case if the ratio is assumed to be constant. In other words, the ratio is always changing due to different illumination for different scenes. That is why; the authors in [1] proposed an adaptive thresholding technique to improve or to solve the problem.

Most of the researchers that develop shadow detection based on this property (*homogeneity*) or image division technique just assume the ratio is always constant and use fix threshold value for the thresholding process (*global thresholding*). In addition, the majority of researchers that use image division technique always use an additional technique after the image division process because the image division process is used to highlight the homogeneity property of shadow especially the umbra region but not penumbra. That is why; they have proposed so many additional processes in order to remove the penumbra region such as multi-gradient analysis [5] and projection histogram analysis [1].

III. THE ALGORITHM

The flowchart in figure 1 shows the main algorithm of the project that has been proposed and the resultant image for every process is shown with an example in figure 4. It has been assumed that the input (*object's blob and background's blob*) is obtained from some background subtraction. All process in figure 1 is explained in the following sections.

A. Image Division

In this process, the object's blob, $ob(x,y), \{x,y \in \mathbb{Z}^2\}$ is divided with the background's blob, $bk(x,y), \{x,y \in \mathbb{Z}^2\}$. It has been said before that the purpose of image division is to highlight the homogeneity property of shadows. Resultant image after the division process is multiplied with a constant for the purpose of increasing the signal of the resultant image. In this case, the constant value is 100 (*Eq.1*). The result of this process is define as $Img\_Div(x,y)$.

$$Img\_Div(x,y) = \frac{ob(x,y)}{bk(x,y)} \times 100, \forall x \in X, \forall y \in Y \quad (1)$$

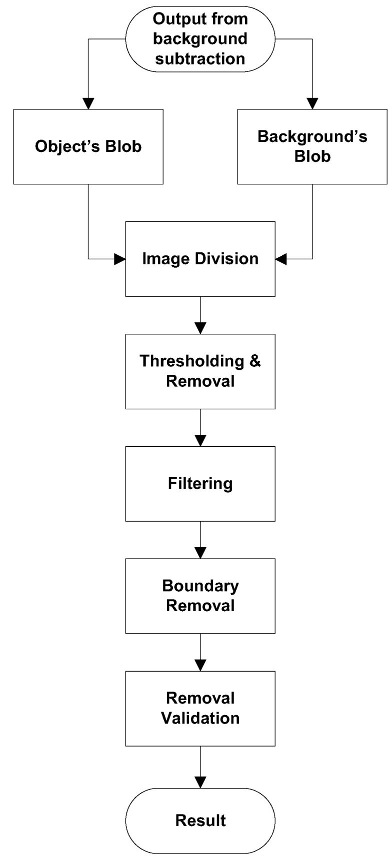

Figure 1. Overall algorithm of the proposed shadow removal technique

B. Thresholding

The purpose of thresholding is to decide the shadow's blob in the resultant image after the image division process (Img_Div). Making use of findings from some researchers [e.g 1,2,3,4], most of the existing approaches mark pixels lying between a certain range of value in the division image as belonging to a shadow.

In [2], the authors set pixels value range of 50-80 ($t\_\min = 50, t\_\max = 80$) as belonging to shadow pixels. However, the range is highly dependent on the illumination in the scene. In addition, different scenes also produce different level at illumination. Authors in [1] had proposed an adaptive threshold in order to solve this type of problem. However, this technique has been tested with a few video samples and it seems that this technique does not work effectively compared to a fixed threshold. It is because the range of adaptive threshold depends on the average value of the division image and this will cause that the threshold value (*range*) that belongs to the shadow change randomly. Because of this problem, in this proposed technique, the range has been set according to the scene (*Eq.2*) and this is done by studying the histogram of the division image over a few samples.

$$Img\_Th = \begin{cases} 1, t\_\min \leq Img\_Div \leq t\_\max \\ 0, otherwise \end{cases}, \forall(x, y) \quad (2)$$

C. Filtering

The purpose of filtering is to enhance the resultant image after the thresholding process (Img_Th) and to find the biggest blob which is predicted as the shadow's blob or shadow region. Filtering process include filling, erosion and dilation to enhance the image and labeling to predict the shadow. It is assumed that the biggest blob after the labeling process or connected component process as a shadow region.

D. Boundary Removal

The purpose is to remove the penumbra region of shadow, or in other words to remove the shadow's boundary. The first step in this process is to get the coordinates of the boundary (*object's blob*). This is also called as boundary tracing process. After that, each boundary pixel and its neighbor is checked whether it is a shadow pixel or not. In this case, neighbor pixels that are only located in the horizontal, vertical, and diagonal (*45 and -45 degree*) of the boundary pixel with certain offset (*range between neighbor pixels and boundary pixel*) are checked.

Figure 2 shows the boundary pixel (*grey colored pixel that is located at the centre*) and the neighboring pixels (*black colored pixels that are located at the horizontal, vertical and diagonal of the boundary pixel*) with an offset value equal to two. So, if the boundary pixel or its neighboring pixels are detected as shadow pixels, the boundary is assumed as a pixel from the shadow's boundary. At this stage, the boundary pixel and its neighboring pixel is removed (*turn the pixel into white color*).

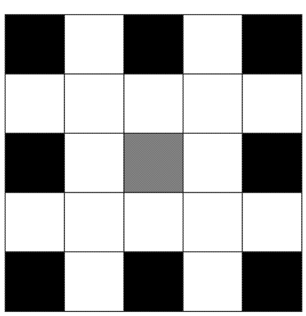

Figure 2. Neighbor pixels checked around a boundary pixel with an offset of two

E. Removal Validation

Removal validation process consists of two sub processes which are the Percentage Checking process and the Vertical Scan process.

The purpose of the Percentage Checking process is to check whether the removal process was correct or not. This is done by checking the percentage of area that has been removed in the removal process (*Eq.3*), where BR represent the percentage of area that has been removed over the area of whole object's blob. Based on the study and analysis of sample images, the shadow removal is correct if the percentage value is within a range that is dependent on a scene (*Eq.4*), where RV, $percent\_min$ and $percent\_max$ represent removal validation result, minimum percentage and maximum percentage (*the range*). This percentage range will be explained later in section IV. If the percentage value does not fall in that range, it is assumed that the removal did not work correctly.

$$BR = \frac{area\ that\ has\ been\ removed}{object's\ blob\ area} \times 100 \quad (3)$$

$$RV = \begin{cases} true, percent\_\min \leq BR \leq percent\_\max \\ false, otherwise \end{cases} \quad (4)$$

The second sub process is the Vertical Scan process which will check which part of the object's blob is predicted as a shadow region. In the Filtering process, it is assumed that the biggest blob after that labeling process is the shadow's region. However, based on the study of input samples, sometimes, the second biggest blob is the correct shadow region and the biggest blob is not a shadow region. Figure 3 shows an example where the Filtering process has done a wrong prediction, and based on the analysis, this biggest blob (*wrong predicted shadow's region*) is always located at the center of the object's blob.

So, in the Vertical Scan process, a vertical scan is performed though the centroid of the object's blob just to make sure that the predicted shadow's region is not located at the center of object's blob. However, the Vertical Scan process can only be applied on certain scenes. Some scenes are not suitable because it will only cause a poorer result.

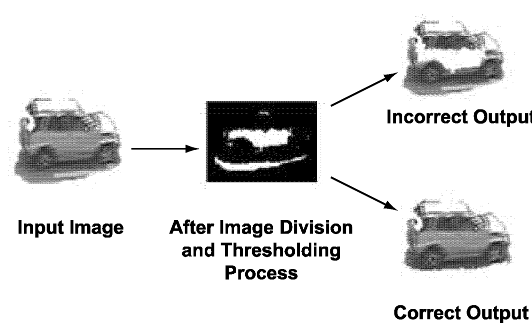

Figure 3. Vertical scan to determine correct removal

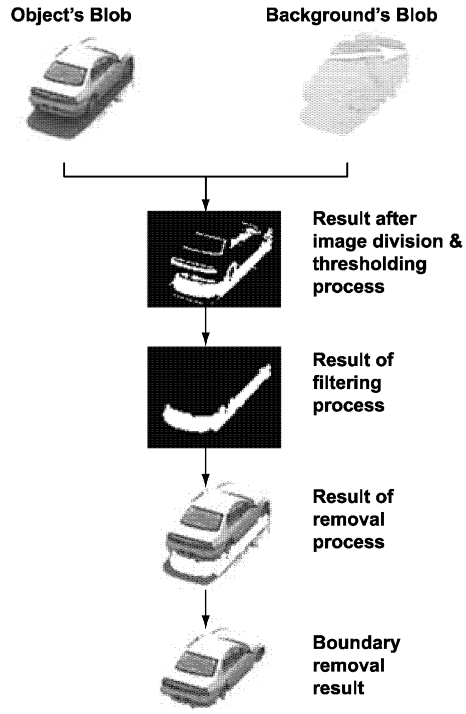

Figure 4. Shadow removal process

IV. Experimental Results And Discussion

In order to demonstrate its usability, the proposed shadow detection and removal have been applied on different types of video sequences and different types of scenes. In figure 5, three results of the shadow detection and removal are presented. In the first scene, the input is shown figure 5a and the output is shown figure 5b. For this scene, the Vertical Scan process is disabled because the object orientation is not suitable application of process. This is also true for the third scene (figure 5e and 5f). In the first scene, the range of shadow pixel has been set from 20 to 50 and the percentage value for the Percentage Checking process (*see Removal Validation process*) is 8% to 45%.

For the second scene (*figure 5c and 5d*), the Vertical Scan process is applied to prevent errors that have been mentioned before, in figure 4. The shadow pixel range is set from 60 to 98 and percentage value for the Percentage Checking process is 8%-33%. For the third scene, shadow pixel range is from 45 to 75 and the percentage ranges are similar to the second scene.

Table 1 show the accuracy or the percentage of correct results based on the scenes that have been shown in figure 5. In each scene, the vehicle is monitored and analyzed for a period of time and the overall success rate is calculated. This is calculated by the percentage of correct result from every video sample, PV_i $\{i = 1..N\}$ (*by getting the number of frames that have the correct result over the number of frames*) and then, to get the average percentage of correct result from video samples in the same scene (PSS). Eq. 5 and Eq. 6 are the formulas that are applied in this analysis where the PV, and PSS represent the percentage of correct result from a video samples, number of video samples in a scene and percentage of correct removal in a scene.

$$PV = \frac{no.of\ frames\ with\ correct\ result}{no.of\ frames\ in\ video\ sample} \quad (5)$$

$$PSS = \frac{\sum_{i=1}^{N} PV_i}{N} \quad (6)$$

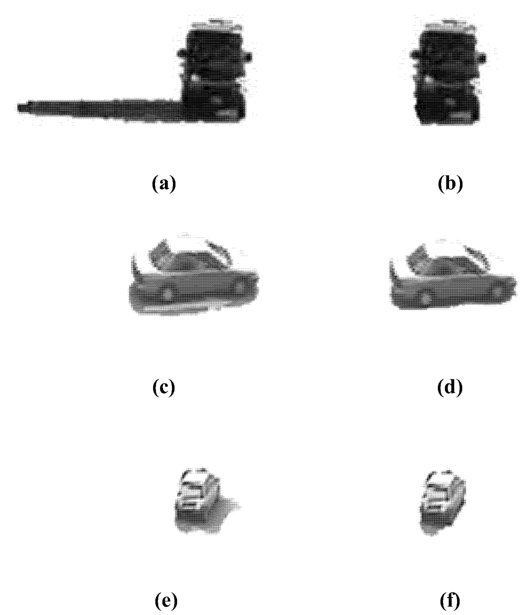

Figure 5. Shadow removal results for several scenes (before a, c, e and after b, d, f).

TABLE I
SCENES AND PERCENTAGE OF CORRECT REMOVAL

SCENE	Percentage of Correct Removal (%)
1st	100.00
2nd	91.39
3rd	69.18

V. Conclusion

A novel method to detect attached shadow has been presented. The target sequence is a daytime traffic scene involving different types of orientation and scenes. Figure 5 shows the result with different types of object size, orientation and scenes.

Working with outdoor images as input is very challenging, as the illumination not only changes slowly as the daytime progresses but may change rapidly due to the changing weather conditions as well as due to the passing objects. So, the proposed technique especially the Removal Validation process will assist the removal process in order to detect whether there are shadows present in an image.

The proposed method improves object detection, which is a very critical task in video surveillance and vision-based traffic monitoring systems.

VI. Acknowledgment

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