

Scene Adaptive Shadow Detection Algorithm

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Abstract— Robustness is one of the primary performance criteria for an Intelligent Video Surveillance (IVS) system. One of the key factors in enhancing the robustness of dynamic video analysis is, providing accurate and reliable means for shadow detection. If left undetected, shadow pixels may result in incorrect object tracking and classification, as it tends to distort localization and measurement information. Most of the algorithms proposed in literature are computationally expensive; some to the extent of equalling computational requirement of motion detection. In this paper, the homogeneity property of shadows is explored in a novel way for shadow detection. An adaptive division image (which highlights homogeneity property of shadows) analysis followed by a relatively simpler projection histogram analysis for penumbra suppression is the key novelty in our approach.

Keywords—homogeneity, penumbra, projection histogram, shadow correction

I. INTRODUCTION

Video motion detection (VMD) is the backbone functionality for most of Intelligent Video Surveillance (IVS) systems. Without a robust motion detection engine, the subsequent functionalities in IVS will not be successful. One of the major challenges in achieving robust VMD functionality is misclassification of shadows attached to moving objects as legitimate moving region. Shadows can cause object merging, object shape distortion etc. causing error in object tracking and classification.

Many algorithms detecting shadows take into account a priori information, such as the geometry of the scene or of the moving objects and the location of the light source. Rest of the algorithms which doesn't require any such a priori information exploits the following sources of information:

- As said above, moving shadows in each frame are attached to their respective obstruction object for the most time - this involves spatial information
- Transparency: a shadow always makes the region it covers darker - this involves the appearance of single pixels
- Homogeneity: the ratio between pixels when illuminated and the same pixels under shadows can be roughly linear - this also involves spatial information

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The algorithm developed in [1] computes intensity ratio image between the current and the reference image for each pixel within the detected blobs. They utilize the characteristics of shadows that the photometric gain with respect to the background image is less than the unity and roughly constant over the whole shadow region, except at the edges (*penumbra* region). From their experimentation results, it is inferred that a priori assumptions regarding with shadow identification rules yield to detect only shadows with a quite large area with respect to the objects itself.

The shadow detection algorithm developed by [2] initially decomposes the difference between the background image and the current image into brightness and chromaticity components. Later, a preset threshold is applied on the separate components. This yields a pixel classification into background, shadow or foreground categories. Experiments have been made for both indoor and outdoor scenes, with only one pedestrian.

The approach described in [3] is applied to gray level images taken by a stationary camera. The authors use the property of moving cast shadows that its illumination change (measured directly from two frames using a physics-based signal model of the appearance of a shadow) is smooth. Authors prepare two distinct modules to detect penumbra and shadows separately. The first module uses the two-frame difference between subsequent frames as the input image. A linear luminance edge model is applied in order to detect likely shadow boundaries. Further, a Sobel operator is measured perpendicularly to the borders and the results are thresholded using both the gradient outcome and the edge model. The second method computes the ratio between two subsequent images and thresholds on the local variance. This algorithm should be heavily adjusted as to work into outdoor scenes as well.

The method presented in [4] similar to the one proposed in [2]: if the difference in both chromatic and brightness components are within some preset thresholds, the pixel is considered as a shadow. The scenes used for the experiments show a high depth of field and blobs as well as shadows are small.

The algorithm explained in [5] initially localized to most likely shadow regions using approach similar to [1] that photometric gain between current frame and reference frame is roughly constant. Later, a multigradient [horizontal, vertical and diagonal edges] operation is performed on the resultant image to remove *penumbra* region. The authors claim their method to be more generic in detecting and removing shadows without the need for any a priori information.

II. MOTIVATION

Those techniques, which are based on homogeneity property for shadow correction assumes that ratio between pixels when illuminated and that are when subjected to shadow is constant. However, our ground truth data shows that the ratio is highly dependent on illumination in the scene and hence shadow correction will not be effective in case if the ratio is assumed to be constant. In addition, these approaches employ computationally expensive techniques like multi-gradient analysis [5] to remove penumbra region, left by image division analysis (previous step). Aimed at improving both functional and speed performance, a hierarchical approach with adaptive image division analysis to identify likely shadow region followed by a relatively simpler projection histogram technique for penumbra region correction is introduced.

III. THE ALGORITHM

The high-level algorithm flow is depicted in Fig. 1. An appropriate VMD algorithm employed in IVS supplies detected blobs of moving objects with its Minimum Bounding Rectangles (MBRs).

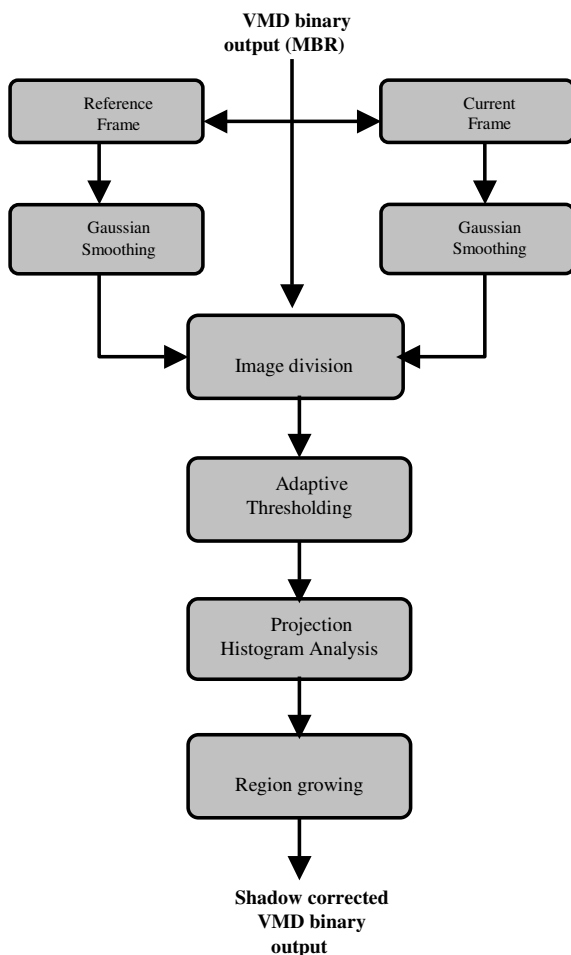


Fig.1. Shadow detection – Algorithm flow

The algorithm further proceeds with following hierarchical processing. It is to be noted that all operations are performed on luminance data within object MBRs.

- 1) Division image analysis
- 2) Projection histogram analysis

A. Division image analysis

In this stage, the homogeneity property of shadows is utilized to localize to likely shadow region. A division image, which highlights homogeneity property of shadows, is computed for each MBR of moving objects independently between smoothed reference image and smoothed input image. The background image obtained as a result of Foreground - Background learning in VMD serves as reference image. In order to make threshold operation more reliable, a scaling factor is applied to division image. Making use of the findings from some researchers [e.g. 1], most of the existing approaches mark pixels lying between a certain ranges of values in division image as belonging to shadow. For example, authors in [5] set grayscale range 50 – 80 as belonging to shadows. However our ground truth data in Table I show that this range is highly dependent on illumination in the scene.

TABLE I.
DIVISION IMAGE ANALYSIS: GROUND TRUTH DATA

Scene	Average [RTOPS ratio]	Average [RTO ratio]	Average [RTS ratio]
	78	62	121
	73	59	96
	87	78	134
	69	54	86

RTOPS ratio : Reference image To Object Plus Shadows ratio

RTO ratio : Reference image To Object ratio

RTS ratio : Reference image To Shadows ratio

As evident from the table entries, the range of values between which shadows pixels lie in the division image is scene dependent. We experimentally found the range to be 1.2 to 1.6 times the average RTOPS ratio. Experimental results shown in Fig. 2 compare performance of division image analysis between fixed threshold and adaptive threshold approaches. Though fixed threshold approach has effectively identified shadow region for first input sequence, one can observe from the figure that it has distorted object region for rest of the sequences. In contrast, the performance of proposed

adaptive threshold approach is optimal in all scenes under consideration.

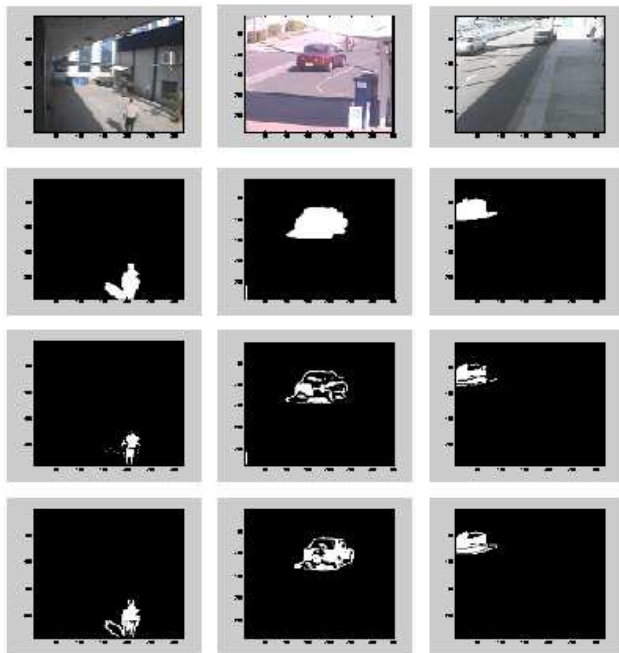


Fig.2. Division Image Analysis – output comparison

Top row : Original Image

Second row : VMD binary output

Third row : Fixed threshold approach

Bottom row : Adaptive threshold approach

B. Projection histogram analysis

As evident from results presented in Fig.2, even though homogeneity property helps in detecting uniform region in shadows, its edge pixels (penumbra) are often left undetected. This necessitates subsequent processing to remove shadows completely. Techniques like multi-gradient analysis [5] developed recently have proved to be very effective in removing penumbra region. However it calls for higher computational requirement due to complex convolution operation involved in gradient calculation. Aimed at addressing this issue, a relatively simpler technique of projection histogram is proposed to operate on division image analysis output for complete shadow correction.

For binary image from division image analysis, column projection histogram (count on number of foreground pixels in each column) and row projection histogram (count on number of foreground pixels in each row) are computed. Column projection histogram and row projection histogram are then normalized with respect to height and width of MBR respectively. Owing to the fact that it contains only fringe region, histogram counts are happened to be minimum along shadows. Fig.3 illustrates sample results based on column projection histogram.

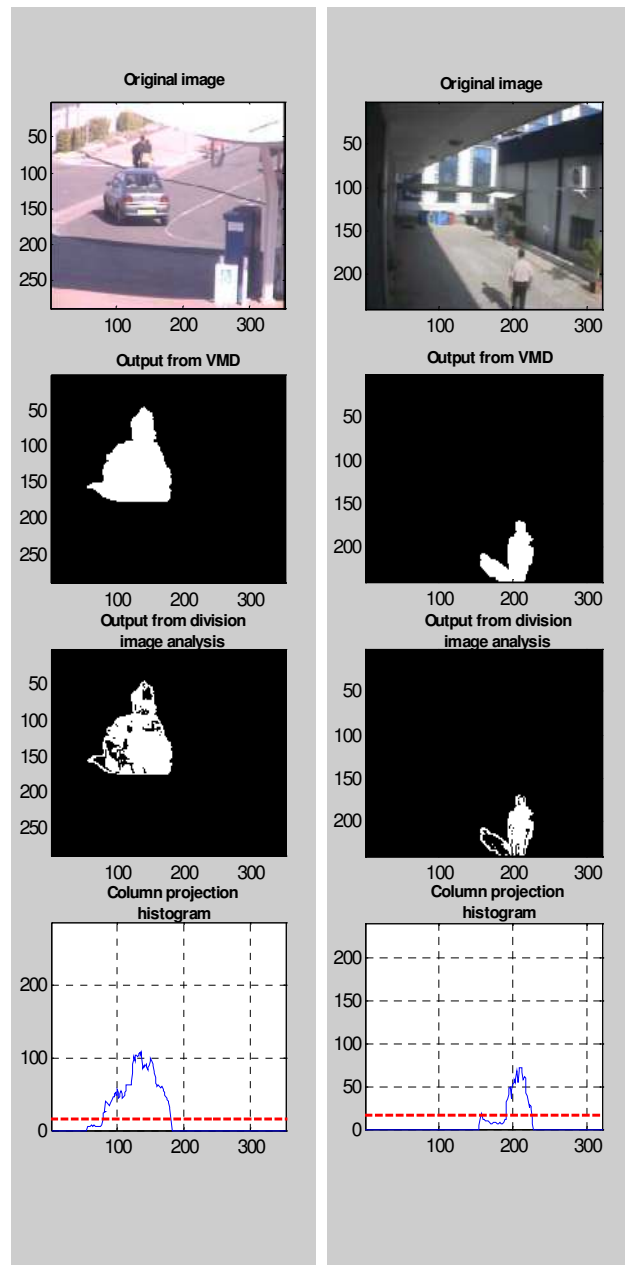


Fig.3. Projection histogram analysis

A preset threshold (shown as dotted line) applied on column histogram count should remove penumbra region from shadow. However, a fixed threshold may affect object shape when it is moving in far field. Hence object parameter (width and height) should also be taken into account while selecting threshold. For example, for images under consideration in Fig.3, a logical AND operation between fixed threshold and fraction of object height has been set as threshold for column projection histogram analysis. Similarly, for shadow suppression involving row projection histogram analysis, the width of the object can be considered for thresholding.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The algorithm has been tested with variety of outdoor video sequence taken from a fixed camera with two different resolutions viz. 352 x 288 and 320 x 240. Results for selected dataset has been presented in Fig. 4. Experiments carried out so far reveals that the algorithm is very effective in detecting moving shadows. It has been proved that suppression of shadows from blobs improve feature computation, which is very critical for object tracking and classification in an IVS system. Except the blocky effect along the boundaries, the integrity of the detected blobs from VMD is preserved to a large extent. It is proposed to use threshold operation based on the change in projection histogram before and after division image analysis rather than fixed threshold to reduce the blocky effect.

V. CONCLUSION

In this paper, a novel approach for robust shadow detection algorithm has been presented. The key claims are of two folds viz., adaptive division image analysis helps in improving the overall functional performance of the system and projection histogram approach ensures that inclusion of shadow detection algorithm doesn't overburden motion detection system.

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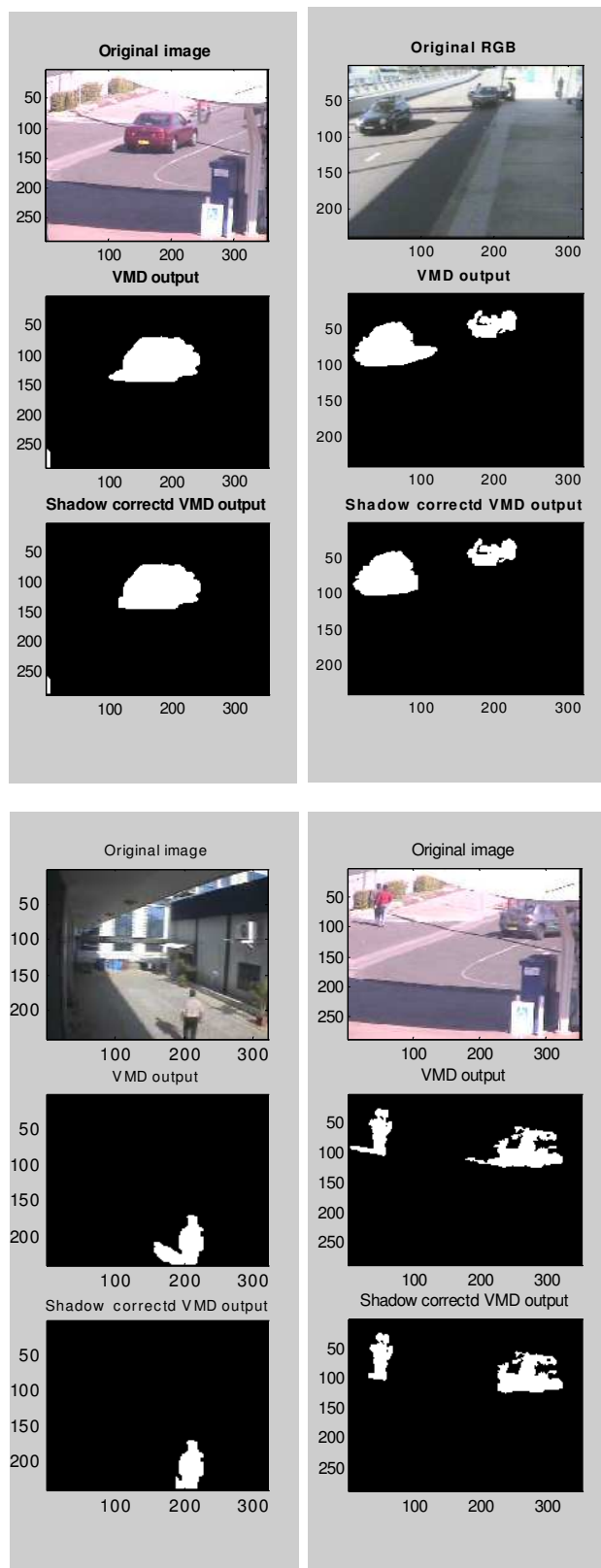


Fig.4. Experimental Results