A Shadow Removal Algorithm for ViBe in HSV Color Space

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Abstract. Shadow removal has always been one of the research hot topics in the field of computer vision. Recently, more and more attention was paid on the ViBe (Visual background extraction) foreground extraction algorithm for its simplicity and high speed. However, for the videos with moving cast shadows, the detection performance is not satisfactory. In this paper, a new shadow removal algorithm for ViBe in HSV (Hue, Saturation, Value) color space is proposed. The ratio of H, S and V components between foreground and background is used to determine whether the interest pixels detected by ViBe are shadows or not. For indoor and outdoor videos with moving cast shadows, ROC (Receiver Operating Characteristic) curve is used to evaluate the proposed approach. Experimental results show that the performance has been improved greatly with the proposed shadow removal approach: for the given TPR (True Positive Rate), FPR (False Positive Rate) is improved even by 11 percentages (for video cubicle).

Keywords: ViBe algorithm • HSV • shadow removal • ROC curve

1 Introduction

One of the key issues of video surveillance is foreground detection technique [1]. Foreground detection algorithms can be divided into three categories: frame difference, optical flow and background subtraction. With the detected foreground, the object information is extracted for further analysis. So, the foreground detection plays a vital role in the surveillance system.

Currently, the most commonly used approach of foreground detection is background subtraction because of its simplicity as well as low computation. It detects a motion area through using the differences between the current frames and the background reference image. If the difference is greater than a certain threshold, the pixel is classified into the moving object area. So, the position, size and shape information of object are gotten with the pixel results of the subtraction operation [2]. In practical applications, it is hard to get a stable background suited

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for the whole image sequence due to the illumination changes or slight jitter of the background. So background subtraction ensures accurate approximation to the actual background by continuously updating the background model. Although updating effectively is the difficulty and key of the approach, the GMM [3] (Gaussian mixture model) motion detection method as the most commonly used method is adopted by many video surveillance systems.

Recently, a background modeling method called ViBe (Visual background extractor) [4] based on probability and statistics has attracted more and more attention due to its simplicity and high speed. The algorithm can suppress the impact of ghosting, camera jitter on foreground detection quickly and effectively with better performance compared with other background subtraction methods. Currently, several related work on the improvement of ViBe algorithm has been reported. M. Van Droogenbroeck *et al.* [5] discussed mainly on the following aspects, distinction between the segmentation mask and the updating mask, respective filtering connected components of regions, inhibition of propagation, increasing adapted distance measure and threshold, a heuristic to detect blinking pixels. Li *et al.* [6] proposed an improved ViBe algorithm based on adjacent frame difference algorithm, which can quickly remove the ghost region and improve the detection accuracy which foreground object through the ghost zone and reduce the false detection rate while preserving the advantages of ViBe algorithm.

The detection of moving cast shadows as foreground objects is very common, producing undesirable consequences. Shadow removal has always been one of the research hot topics in the field of computer vision [7-10]. Although with the advantages described above, the performance of ViBe algorithm needs to be improved when applied to complex background, especially in the case of moving cast shadows. So a new shadow removal algorithm for ViBe in HSV (Hue, Saturation, Value) color space is proposed in this paper, which can improve the accuracy of the foreground detection in the present of moving cast shadows. The rest of the paper is organized as follows. In Section II, the ViBe algorithm is introduced firstly, and a new shadow removal algorithm for ViBe in HSV color space is proposed. Experimental results and analysis are presented in Section III. Section IV draws the conclusion.

2 ViBe Foreground Detection Method

The ViBe algorithm adopts neighboring pixels to build the background model, detect objects by comparing the background model with the current input pixel values to. The procedure is divided into following three steps, namely model initialization, foreground detection, and model updating. The first background frame is initialized only with the first frame of the video. Background models are made of 20 background samples for each pixel. Then subsequent input frames are executed with foreground object segmentation while updating the background pixel model. The last step is to select updatable neighbor pixels which are determined as the background pixel randomly. Background samples are selected randomly to update the model while other samples are discarded. There is a spatial propagation mechanism that inserts background values in the models of neighboring pixels. Once the random policy decides to substitute a value of the model, it also inserts that value in the model of the neighboring pixels. The algorithm is operated on individual pixel $f(x,y)$, as shown in Fig. 1.

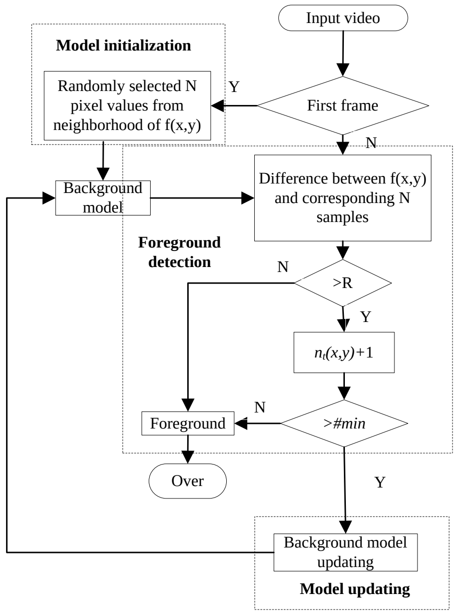

Fig. 1 Block diagram of ViBe algorithm, the parameter R is preset as the matching threshold (which in RGB space is a spherical radius), $n_t(x,y)$ as the number of matching pixels, *#min* as the threshold of minimum number of matches.

3 Shadow Removal Algorithms in HSV Color Space

3.1 Shadow Removal in HSV Ccolor Space

The proposed shadow removal method is developed according to the following observations. The brightness of the shadow region is lower than that of the background area. Chrominance and luminance information can be effectively separated in the HSV color space. So HSV color space is commonly used to detect and remove shadows [7], as shown in following (1).

$$SPoint(x,y)=\begin{cases} 1 & \alpha \le V^I(x,y)/V^B(x,y) \le \beta \wedge \\ & |S^I(x,y)-S^B(x,y)| \le \tau_S \wedge \\ & |H^I(x,y)-H^B(x,y)| \le \tau_H \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where $I(x,y)$ and $B(x,y)$ are the pixel values at coordinate (x,y) in the current frame and the background reference image, respectively. The first condition works on the luminance component. The use of β prevents the identification of those points where the background was slightly changed by noise as shadows. But the "power" of the shadow is taken into account, *i.e.*, how strong the light source is with regard to the reflectance and irradiance of the objects. Thus, the stronger light identified is, the lower α should be chosen. For component S, the threshold τ_S on the difference between the current frame and the background are performed. Shadows lower the saturation of points and the above difference is usually negative for shadow points. The threshold τ_H on the absolute difference turns out better results considering component H.

3.2 System Framework

As described above, the shadow removal algorithm for ViBe in HSV color space is also operated on individual pixel $f(x,y)$. The basic idea is summarized as follows. Firstly, ViBe algorithm is used to detect the foreground regions (including shadows) and the background frame is obtained through GMM algorithm. After both of the foreground and background pixel values for pixel $f(x,y)$ are detected, attributes of shadows are taken into account to detect the shadows in the HSV color space and removed from the foreground. Finally, the foreground without the influence of shadows is segmented. The block diagram is shown in Fig. 2.

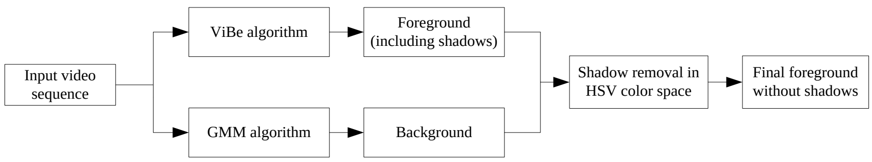

Fig. 2 The block diagram of shadow removal algorithm for ViBe in HSV color space

4 Experimental Results and Analysis

4.1 Description of Test Videos

There are obviously moving cast shadows in the test videos of Bungalows, san and cubicle [11], as pointed out in Tab. 1.

Table 1 Characteristics of test videos

No.	Video	Video type	Motion type	Light	Color of shadow	Area of shadow
1	Bungalows	outdoor	Single car	Stronger	darker	bigger
2	san	outdoor	Multiple car	Weaker	darker	smaller
3	cubicle	indoor	Single person	Strongest	light	bigger

4.2 Experiment of Shadow Removal

We use the above videos to test the algorithm and draw ROC (Receiver Operating Characteristic) curves [12]. The results are presented in Fig. 3, where ViBe_FG1 is the result of original ViBe algorithm, ViBe_FG2 indicates result after shadow removal. For comparison, the GMM algorithm is also tested and the result is denoted as GMM_FG. According to the characteristics of test videos and the meaning denoted by each component of HSV color space, parameters of the approach in each video are set hereafter. Video Bungalows: α=0.3, β=0.5, τ_S =0.4, τ_H =0.6. Video san: α=0.2, β=0.4, τ_S =0.4, τ_H =0.6. Video cubicle: α=0.6, β=0.8, τ_S =0.7, τ_H =0.9.

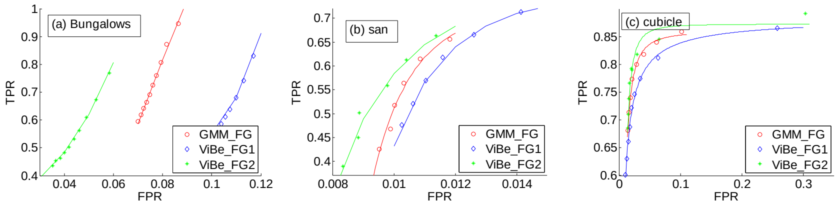

Fig. 3 Comparisons between ROC curves of three approaches

As shown in Fig. 3, for video Bungalows, while keeping TPR (True Positive Rate) at 60%, FPR (False Positive Rate) of GMM and ViBe algorithms are 7.5% and 11%, respectively. The corresponding FPR is 5% after shadow removal, improved even by 6 percentages. For video san, while keeping TPR at 50%, FPR of GMM algorithm and ViBe algorithm are 1% and 1.08%, respectively. The corresponding FPR is 0.91% after shadow removal, improved by 0.17 percentages. For video cubicle, while keeping TPR at 85%, FPR of GMM algorithm and ViBe algorithm are 8% and 15%, respectively. The corresponding FPR is 4% after shadow removal, improved even by 11 percentages.

It can be drawn that the performance of the proposed approach is better than the original GMM and ViBe algorithms for the testing videos. We also get similar results through experimenting on other more video tests that can't be shown at here for the limited space.

4.3 Analysis with Pictures From the Test Videos

Based on the above results, analysis with specific pictures from each test video is detailed as follows.

4.3.1 Video Bungalows

The first video that we analyze is the outdoor video Bungalows with moving cast shadows only. The results of 364th frame are shown in Fig. 4.

(a) (b) (c) (d) (e)

Fig. 4 Results of the 75th frame in video Bungalows: (a) the 364th frame of video (b) ground truth (c)–(e) results of the original GMM algorithm, the original ViBe algorithm and the proposed approach, respectively.

Comparing Fig. 4 (b) with (c), we can find that a more complete region is detected by GMM algorithm. However, some false alarms mainly caused by the moving cast shadows of the car and some missing alarms inside the car are both emerged. Comparing Fig. 4 (c) with (d), the correct detection rate of ViBe algorithm is slightly lower than that of GMM algorithm while false alarms are unchanged. Comparing Fig. 4 (c), (d) with (e), false alarms are suppressed to a great extent after shadow removal. So removing shadows have greatly improved the performance of ViBe foreground detect algorithm.

4.3.2 Video san

The second video san is an outdoor video, whose environment is much more complex. It not only consists of moving cast shadows, but also includes the shaking leaves and other dynamic background causing interference to foreground detection. The results of 75th frame are shown in Fig. 5. Comparing Fig. 5 (b) with (c), owing to the interference of moving cast shadows and dynamic background, a high false alarm is detected by GMM algorithm. Comparing Fig. 5 (c), (d) with (e), ViBe algorithm gets a better result by reducing false alarms with a larger area compared to GMM algorithm. It only detects a little part of moving cast shadows and dynamic background, effectively reducing false alarms through shadow removal.

(a) (b) (c) (d) (e)

Fig. 5 Results of the 75th frame in video san: (a) the 75th frame of video (b) ground truth (c)–(e) results of the original GMM algorithm, the original ViBe algorithm and the proposed approach, respectively.

4.3.3 Video cubicle

The third video cubicle is the indoor video with more complex environment. Not only moving cast shadows but also the strong illumination has caused interference to foreground detection. The results of 1224th frame are shown in Fig. 6. Comparing Fig. 6 (b) with (c), plenty of interference due to the moving shadows and strong illumination is detected by GMM algorithm. Comparing Fig. 6 (c), (d) with (e), ViBe algorithm gets a better result by eliminating the affection of interference compared to GMM algorithm. It only detects a little part of moving cast shadows and strong illumination, and false alarms are reduced through shadow removal effectively.

(a) (b) (c) (d) (e)

Fig. 6 Results of the 1224th frame in video cubicle: (a) the 1224th frame of video (b) ground truth (c) – (e) results of the original GMM algorithm, the original ViBe algorithm and the proposed approach, respectively.

As shown in all above results, the original GMM and ViBe algorithms will inevitably be affected by the interference of moving cast shadows. The proposed shadow removal procedure can effectively eliminate the influence of moving cast shadows and improve the performance of the system.

5 Conclusion and future work

A new shadow removal algorithm for ViBe in HSV color space is proposed to eliminate the impact of moving cast shadows for the foreground detection. For both indoor and outdoor videos, ROC curves indicate that a relatively obvious improvement has achieved and the proposed algorithm outperforms both algorithms of the original GMM and ViBe significantly. However, following issues have come along with it as well: 1) there is still a small part of shadows can not be removed around the inside part of the car (for video Bungalows) and near the human foot (for video cubicle); 2) the algorithm still can not eliminate the impact on foreground detection for indoor video with strong illumination.

Future work is to reduce the false detection rate while raising the correct detection rate. Available methods are as follows: 1) Getting the threshold of each component in HSV color space more effectively or removing shadow in other color spaces; 2) adding modules of eliminating the impact on strong illumination to the existing foreground detect algorithm.

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