Stain Detection in Video with Background Restructured

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***Abstract*—Nowadays, multimedia, especially video, is used widely in many domains. But camera lens are easily stained because they are always outside, such as in traffic and monitoring. Admittedly, the video from these cameras is out of action because it cannot provide clear frames. In this paper, we provide a detecting method from video with background restructure. This method is presented to detect stains in video. Firstly, the first video frame is used as a pseudo-background because original cameras are clear with no stains. Then, background is constructed by the pseudo-background and the continuous frames which are from the video. Moreover, with training in the frames, we restructure background by dropped moving objects in it. Finally, after background restructured, we detect stains in camera lenses by the restructured background, and provide positions of stained area. Experimental results show its robustness and practicability.**

***Index Terms*—Background Restructured; Background Robustness; Stain Detection; Video Stain; Practicability**

I. Introduction

Nowadays, with development of information technology, network cameras are used widely in many areas. Today, it becomes an important application in many domains, e.g. military affairs, national defense and so on [1-2]. It uses background and current frame to detect stains on cameras. Nowadays, we always use background subtraction method to detect camera stains [3]. But a major problem in this method is that the camera must recognize the stability of all extra objects in video. It is because that moving objects and stains must be separated. So we must track trajectory of all moving object, and then gain stains in a video. So in this paper, we restructure background with a method fusing background subtraction method and temporal difference method, and then track trajectory and detect stains.

When we use background subtraction method to catch moving objects, we must construct a pixel model of background at first. In this paper, we use temporal difference method to restructure the background by comparing differences in continuous three frames [4]. In fact, its computation amount is small for background subtraction method and its accuracy is well enough for temporal difference method. It has robustness with transformations of illumination, noise and other nature characters.

The threshold of differences in continuous frames is key matter of temporal difference method. Moreover, a moving object is detected when differences are larger than the threshold. This method is robustness with transformations of illumination and shadow. But the threshold needs to select well, otherwise, there will be large void or miss object when threshold is too large and large noise when threshold is too small. However, this method cannot treat those objects which stay at a position for a long time, and it do not process well when movement is not uniform [5-6].

Nowadays, there are lots of study of moving tracking and capture in many areas [7-9]. But there is no suitable way to solve stains in videos. So in this paper, we put forward a new tracking and detection method without origin background. In our opinion, we detect stains in cameras by avoided moving objects with or without movement. So in our method, we use temporal difference method to restructure background at first. Then we detect stains by using background and moving trajectory.

In the following sections, we present our work in the following order.

At first, in Section 2, we present our method and model, which using background restructuring method by temporal difference and mathematical morphology method.

Then, in Section 3, we further track trajectory by using background restructured, and then we find those static trajectories and separate stains where they were moved before.

Moreover, in Section 4, we use experimental result to validate robustness and practicability of our method.

Finally, in Section 5, we summarize this paper.

II. Background Restructured

A. Temporal Difference Method

In this paper, we use temporal difference method to detect points of background by Eqs. 1-2 and inequation.3. Firstly, we create a function $G_{i,j}$ to compute difference for

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two continuous frames X_{i-1} and X_i. Then we use another function Bi,j to show if there are moving objects in these frames. Next, when applying In(x) as pixel gray of nth fore-frame and Tn(x) as threshold, we consider pixels z is moving when it fits Inequation.3 and not when contrary. So when the moving objects moves between frames, we can train to find all background points. Flow chart of background training is shown in Fig. 1.

$$G_{i,i-1}(x,y) = |X_i(x,y) - X_{i-1}(x,y)| \quad (1)$$

$$B_{i,i-1}(x,y) = \begin{cases} 1, & \text{if } G_{i,i-1}(x,y) \geq \text{threshold} \\ 0, & \text{Otherwise} \end{cases} \quad (2)$$

$$\begin{aligned} |I_n(x) - I_{n-1}(x)| > T_n(x) \\ |I_n(x) - I_{n-2}(x)| > T_n(x) \end{aligned} \quad (3)$$

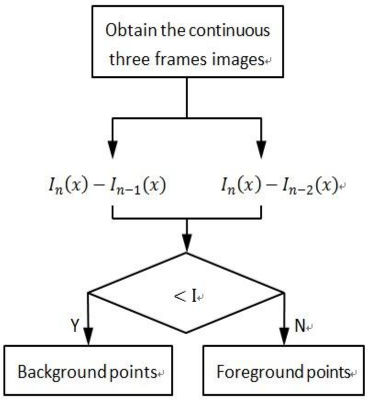


Figure 1. Restructure background with training

B. Restructuring Method of Background

When an object moves, there are some shaded points of background displayed. With our restructuring method, we find these static points and put them into a new frame. This new frame can be called restructuring background. Then, we train frames of a video some time to fill the restructuring background. Admittedly, points of background are changed when there are changes of illumination, wind (mainly outside) and other elements.

As we known, the movement and environment are usually unpredictable. For example, intense movement can bring sharp or fuzzy border and strong illumination and elastic deformation also shows negative detection. It means that this problem is also in the background we restructured. So we need to use some methods to compensate the background we restructured.

In fact, we need to modify its structure when we take clear and complete background. In our work, we use mathematical morphology to modify the background. Specifically, we use erosion to fill small hole and dilation to remove isolated noise. To use them in special order, we get opening and closing operation derived from erosion and dilation.

When we call B_z as translation of structure element B, we use Eq. 4 to give the dilation. Form Eq. 4, we have that dilation X_d is a set construct with all points, which makes B_z and X are not empty set. Furthermore, with this expanded process, the exchanged result expands background and fills empty holes in X_d. So we use Eq. 4 to reduce empty holes in background and initialize it to a connected domain.

$$X_d = X \oplus B_z \quad (4)$$

Oppositely, erosion is such a set construct with all points z, which makes B_z is a subset of X. We use E.q.5 to express it. Erosion is a process of shrink transform to remove boundary points. The exchange result X_e expands empty holes and shrinks background. In this way, we use erosion to remove isolated noise point actively.

$$X_e = X \ominus B_z \quad (5)$$

Generally, both erosion and dilation are irreversible operations. It means that the result always differs to X when we transform X by using Eqs. 4-5 step by step. Then, when we use Eq. 4 at first, then use Eq. 5, we have the result X_o in Eq. 6. In contrary, when we use Eq. 5 at first, then use Eq. 4 behind, we can have another result X_c in Eq. 7.

In Eq. 6, we find that this presented novel morphological transformation is an opening operation because X_o is constructed by the set of B_z, which is translation of B. Otherwise, it always smooth border of the exist background, and it removes small sharp or isolated points. Furthermore, it sharpens angles, disconnects limited gaps and removes thin tips.

Then, with same analysis, we know X_c is an closing operation from Eq. 7. It transforms X by dilation firstly and erosion secondly. In this case, X_c is a complementary intersection set of all translations B_z, and it outside X. We use this morphological transformation to smooth border, remove limited gaps and long thin blanks like opening operation. Moreover, it removes small holes and fills boundary ruptures.

$$X_o = (X \ominus B_z) \oplus B_z = \cup \{B_z^c : B_z \subset X^c\} \quad (6)$$

$$X_c = (X \oplus B_z) \ominus B_z = \cup \{B_z^c : B_z \subset X^c\} \quad (7)$$

So, in the next step, we execute several transformations by Eqs. 6-7 to reach continuous background. Then, with both temporal difference method and morphological transformations, we restructure the background by trained several frame teams.

III. Stains Detection and Trajectory Tracking Method

With background restructured, we can detect stains in monitoring videos. In fact, the background is static in monitoring cameras. So we research in differences of frames with fixed distance. Then, we compare static area without background and then use morphological transformations to process. We detect a stained area and send administrator messages when area of one static region is more than a threshold.

But this process has shortcomings. For example, there is a video for a part of a classroom, and original background is an empty desk. Then someone puts a book on it. This will lead to a wrong detection because the book is detected as a stain. So we should use trajectory tracking method in our method [10-11]. We track trajectories of all moving objects with their differences are less than a threshold in continuous frames.

We use E.q.8 as basic shift formula [12].

$$\mathrm{M_h}(x) = \frac{1}{k}\sum_{x_i \in S_h}(x_i - x) \quad (8)$$

where

$\mathrm{S_h}(x) \equiv \{y: (y-x)^T(y-x) \leq h^2\}$

It is known that a point is more effective of statistic characteristics estimation x when it is nearer to x. So we use distance into Eq. 8, and give an improved tracking method with Eq. 9.

$$\mathrm{M(x)} = \frac{\sum_{i=1}^{n} G_H(x_i - x) w(x_i)(x_i - x)}{\sum_{i=1}^{n} G_H(x_i - x) w(x_i)} \quad (9)$$

Then, to set them in kernel function we have E.q.10 to describe the trajectory, and Eq. 11 must be a maximum likehood of Eq. 10. So we use Eq. 12-13 to give the final tracking method by simplified formulas.

$$\widehat{q_u} = C\sum_{i=1}^{n} k\left(\left\|\frac{x_i^s - x_0}{h}\right\|^2\right)\delta[b(x_i^s) - u] \quad (10)$$

$$\widehat{p_u}(y) = C_h\sum_{i=1}^{n_h} k\left(\left\|\frac{x_i^s - y}{h}\right\|^2\right)\delta[b(x_i^s) - u] \quad (11)$$

$$\mathrm{w_i} = \begin{cases}\sum_{u=1}^{m}\delta[b(x_i) - u]\sqrt{\frac{q_u}{p_u(y_0)}} & when\ i = 1\\ 0 & otherwise\end{cases} \quad (12)$$

$$\rho[\mathrm{p(y), q}] = \begin{cases}\frac{1}{2}\left\{C_h\sum_{i=1}^{n} w_i k\left(\left\|\frac{y - x_i}{h}\right\|^2\right)\sum_{u=1}^{m}\sqrt{p(y_0)q_u}\right\} & when\ i = 1\\ \frac{1}{2}\sum_{u=1}^{m}\sqrt{p(y_0)q_u} & when\ i = 0\end{cases}$$

In this way, we research features of the stains, and find a difference area is a stain where it is a static object which differs to background and it is appeared suddenly. In other words, this static object is not appeared in previous frames sequence. Therefore, this kind of objects is probably a stain. Admittedly, camera movement is also detected as a stain. In fact, this step is possible because our final objective is to find all cases that makes monitor cannot photo/film what we need.

The process of the novel method is shown in Fig. 2.

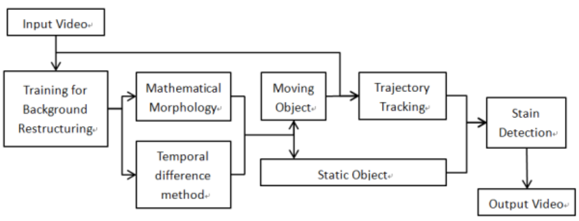


Figure 2. Process of the novel stains detection method

IV. EXPERIMENT AND ANALYSIS

The first experiment is moving object capture from a video which is filmed outer of my office window by a camera. The background is full of noises because of wind and illumination. We show some images caught from video in following figures. Upper left of each image is filmed time. The form is yyyy-mm-dd hh-mm-ss. At first, we give our restructured background in Fig.3. We train it for a short time that there are some static cars are detected as background. It is because they do not move after we film our video. Then, we stain the camera lens in Fig.4-7. We use soil on the camera to simulate stains on it. Moreover, we use the stained camera to film another video and have some frames from it, which are shown in Fig. 4-7 by time sequence.

Figure 3. Original background outside

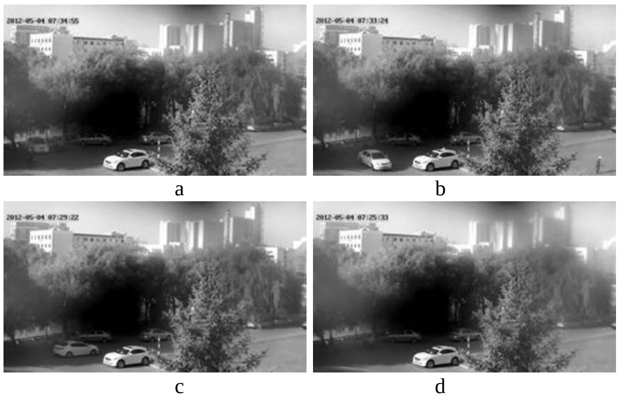


Figure 4. Stained video frames

In this way, we use the stains detection method to process these frames of the video and the results are shown in Fig. 5.

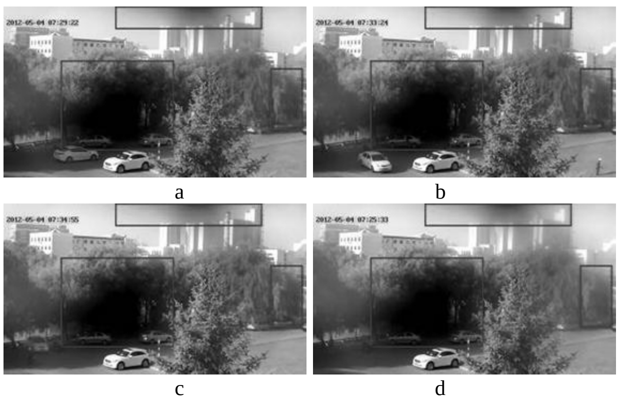
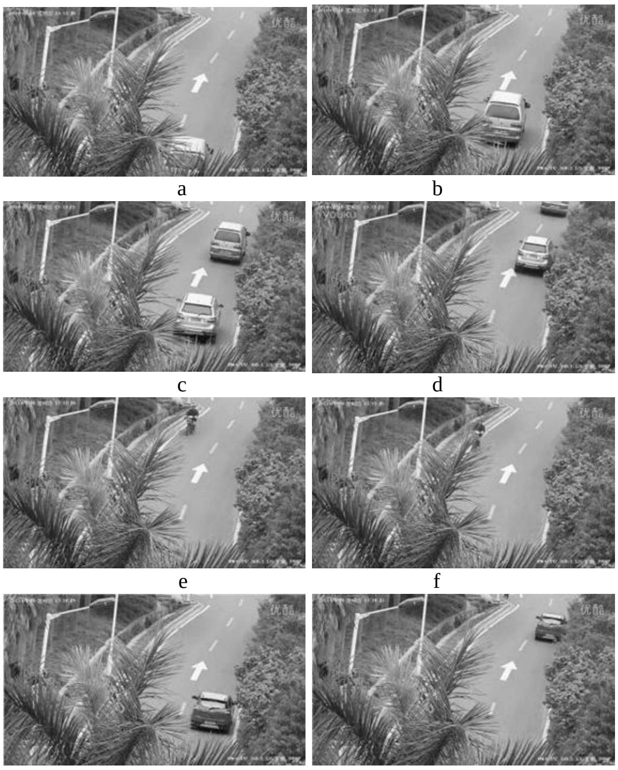


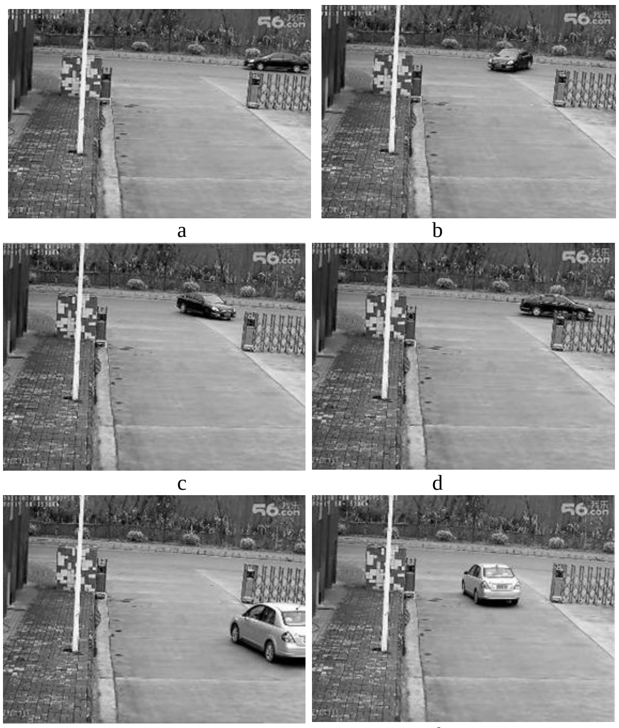
Figure 5. Stains detection of stained video frames

Then, we use some video fragment from websites to validate our method [13-15]. Unfortunately, we do not find videos with stains. So we use a stain randomized algorithm to create stains for these videos, and then add these stains into these videos separately. Original frames of these videos are shown in Figs. 6-8.



a b c d e f g h

Figure 6. The first monitoring video fragments



a b c d e f

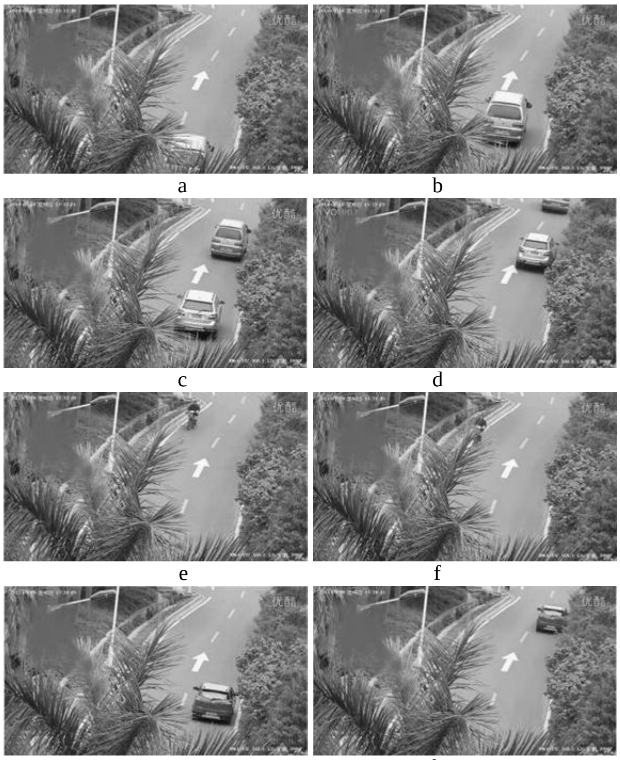
Figure 7. The second monitoring video fragments

a b

c d

Figure 8. The third monitoring video fragments

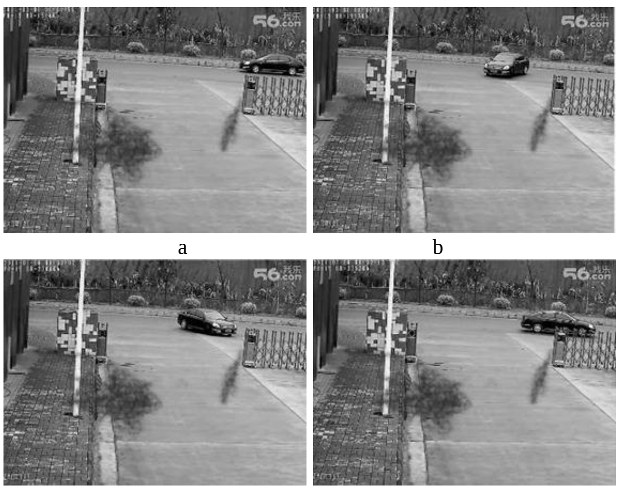
The corresponding stained frames are shown in Fig. 9-11.



a b c d e f g h

Figure 9. The first stained monitoring video fragment

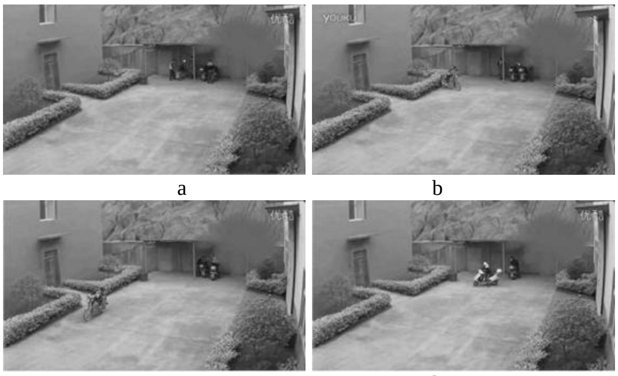
Moreover, the stains we created are shown in Fig. 12. Fig. 12a is the stain for the first monitoring video, Fig. 12b is the stain for the second monitoring video, and Fig. 12c is the stain for the third monitoring video.



a b c d

e f

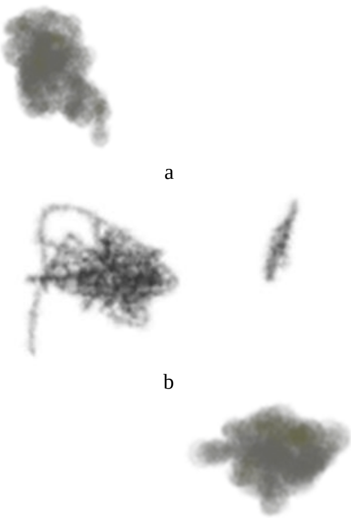
Figure 10. The second stained monitoring video fragment



a b

c d

Figure 11. The third stained monitoring video fragment



a

b

c

Figure 12. Three stains

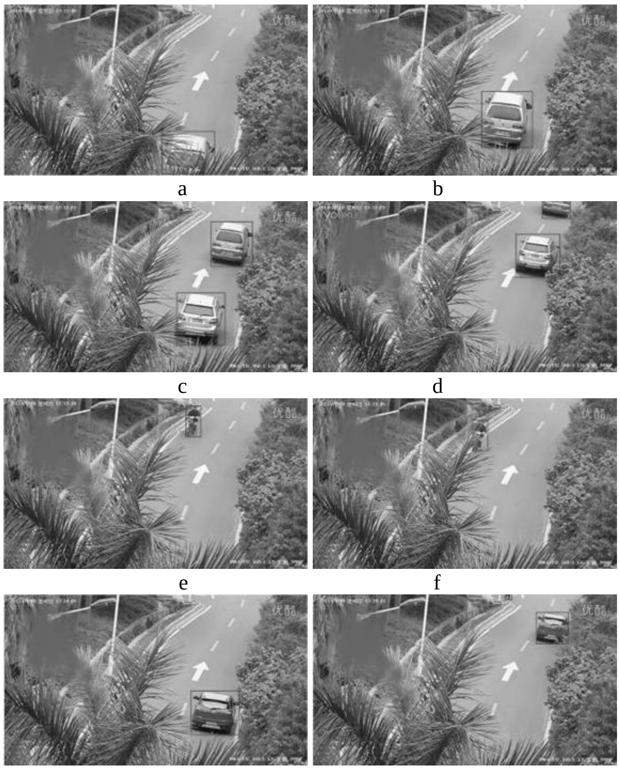
Figure 13. The first background

Then, we use our stains detection method in these videos, and get the background of all videos in Figs. 13-15. Meantime, I have to say that we cannot process displayed time on top left because the time changed tinily that we cannot detect time as moving or static object. We can only treat them as background.

Figure 14. The second background

Figure 15. The third background

Meanwhile, we reach the moving trajectories of these three videos. They are shown in Figs. 16-18.



a b

c d

e f

g h

Figure 16. Trajectory tracking in the first stained monitoring video fragment

Figure 17. Trajectory tracking in the second stained monitoring video fragment

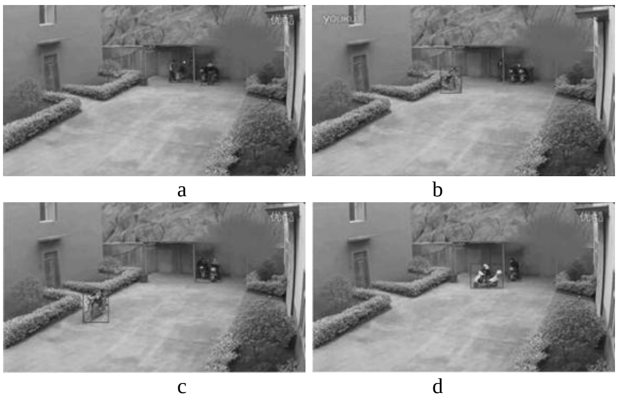
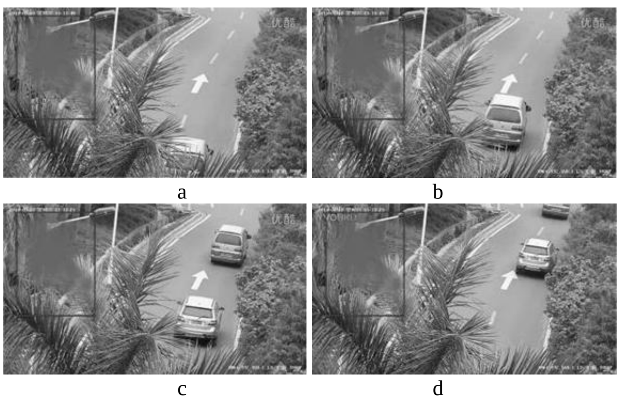


Figure 18. Trajectory tracking in the third stained monitoring video fragment

Finally, we reach the stains of these three videos. They are shown in Figs. 19-21.



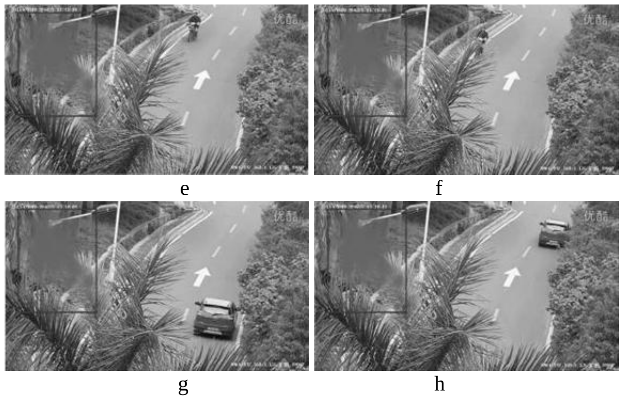


Figure 19. Stain detection in the first stained monitoring video fragment

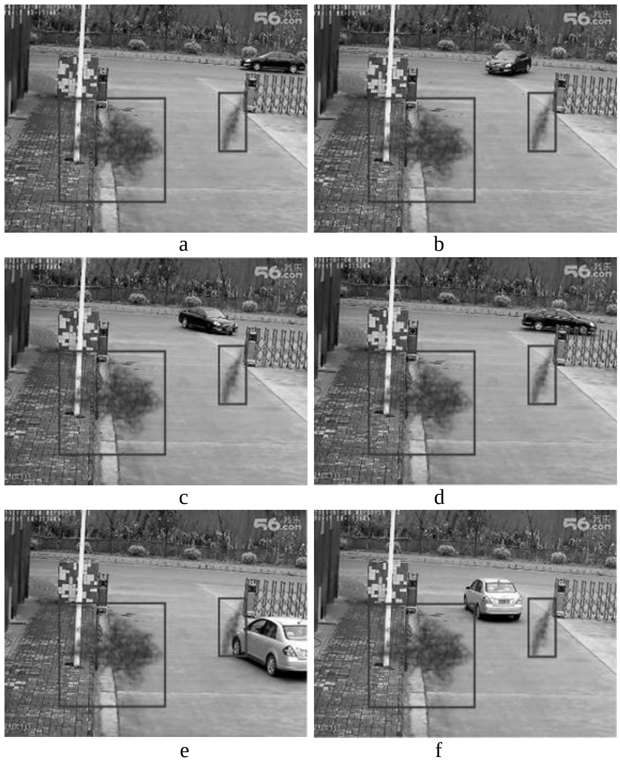


Figure 20. Stain detection in the second stained monitoring video fragment

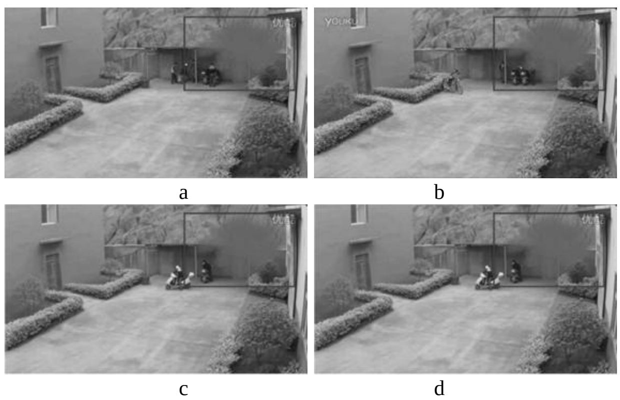


Figure 21. Stain detection in the third stained monitoring video fragment

V. Conclusion

This paper puts forward a stain detection method in network monitoring video with background restructured. In this paper, we restructure background by using both temporal difference method and morphological transformations. Then with the trained background, all moving trajectory and static trajectory are detected. Moreover, with stain detection method, we separate static trajectory to stains and static objects with movement. This judgment is given by detecting if these objects were moved before in the video. This method is antinoise when we set a threshold to separate moving fragments and noise. Admittedly, these noises may be created by any condition, e.g. illumination and wind. Finally, we process experiments to validate our method. Experiment results show its positive computational complexity, accuracy and robustness.

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