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Moving Target Detection Algorithm for Forest Fire Smoke Recognition with Improved ViBe

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Abstract. In order to discover the forest fire at the early stage, the video based fire smoke detection system should be developed. This paper proposes an improved ViBe algorithm to overcome the drawbacks of ViBe which is widely used in forest fire smoke recognition. To make the algorithm faster, the improved ViBe algorithm introduces a switch variable to control the model updating every 2 frames. Also, the new ViBe algorithm contains a method to detect if the scene is changing, and upon finding the changing, a fast updating strategy would be used to increase the adaptive ability. The experiments are done from 2 aspects, to test the time consuming and adaptive ability of the improved algorithm. The experiments results show that the improved ViBe algorithm has better performance compared to ViBe algorithm and GMM algorithm, and can detect the forest fire smoke accurately in different conditions.

1. Introduction

Forest fire is one of the most harmful disasters which damages the ecological environment and causes serious loss of lives and properties. The detection of the forest fire in the early stage has become the hottest issue these years. [1] [2] To find out the forest fire as soon as possible, the smoke detection is necessary. The video based recognition algorithm for fire smoke in forest is using some intelligent algorithms to analyze the video and extract the feature of the smoke, which can help us recognize the fire smoke more accurate and earlier. [3] The moving target detection algorithm is one of the essential parts of these algorithms.

The background subtraction method is the mainstream of the moving target detection algorithm. The basic idea is to calculate the difference between the current image and the background model to see if the current image is foreground or not. [4] The method has good performance when applied to the complex environment but is sensitive to the change of the scene. Gaussian Mixture Model (GMM) is a common background subtraction method. [5] It will establish a Gaussian model for each pixel and if the new pixel value can match the Model, we consider the pixel as background. [6] GMM has obvious shortcoming which can hardly use on real time video analysis according to its large computational complexity. [7] Barnich proposes a new background subtraction method called ViBe which establishes the model by randomly collecting the pixel value from the neighborhood. [8] Compared to the other model in background subtraction method, ViBe needs less computational memory and improves the speed apparently. [9] However, ViBe still has some drawbacks and there has been some specialist giving their opinions to improve ViBe. Ahong Xu et al. propose a method that



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uses the dynamic threshold to make the detection more accurately. [10] Wang Biao modifies the algorithm by removing the ghost region when initiate the model. [11] Shanyi Liu uses spatial temporal gradient to improve the detection accuracy.

This paper proposes an improved ViBe algorithm which has a better performance when applied to the forest fire smoke recognition. For further improvement on the speed, a switch variable is introduced to control the updating of the model in the new ViBe algorithm. In addition, the new ViBe algorithm contains a method to detect the scene switching. Once finding that the scene switched, a faster updating strategy will be carried out.

2. Principle of the ViBe Model

The main idea of ViBe is to establish the model by make a collection of samples for each pixel. Each collection consists of N samples which are randomly picked from the eight-neighbor of the pixel. It will know if the new pixel belongs to background or not by comparing to the samples in collection.

The first step of ViBe is to initiate the model which refers to filling the collections by randomly picking the samples from the neighborhood. We assume that the background model is $M(x)$ which contains N samples. In equation (1), p_i represents the value of the i th sample.

$$M(X) = \{p_1, p_2 \dots p_n\} \quad (1)$$

For identifying the similarity between the new pixel and the background model, we define a circle $S_R(p(x))$ with radius R who has a center $p(x)$, seen in Figure 1.

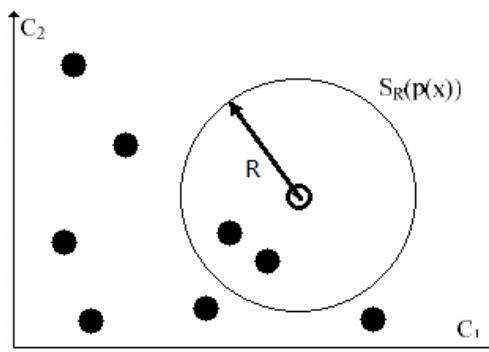


Figure 1. Comparison between the new pixel and the background model

U is a collection which represents the intersection of the background model $M(x)$ and the circle $S_R(p(x))$, seen in equation (2). The number of the elements in U shows the similarity between the new pixel and the background model.

$$U = \{S_R(p(x)) \cap M(x)\} \quad (2)$$

According to equation (2), the Euclidean distance between $p(x)$ and the N samples should be calculated and make a comparison to R . If the distance is smaller than R , we consider that the pixel matched this sample. Upon finding U_{min} samples in the background model that can match to the pixel, the pixel will be regarded as background.

According to the change of the background, the model should be updated from time to time. ViBe mainly follows 2 updating rules:

(1) If a pixel is determined as a moving target for a long period, there must be an error occurring before. It will be turned into background.

(2) If a pixel is considered as background, there is a possibility of $1/\varphi$ to update the collection it correspond to. φ is the updating rate which determined the life period of the samples in the collection.

3. Improvement on ViBe Algorithm

When we apply ViBe to the forest fire smoke detection, we need to process the video high frame rate.

Also, the cameras that monitor the forest would change the monitoring angle from time to time. So we often face the following 2 problems when using original ViBe algorithm:

(1) Although ViBe is slightly faster than GMM model and some other algorithms for detecting the moving target, it can hardly handle the real time video, especially the video with high frame rate.

(2) When the scene is changing, it will take some time for ViBe to adapt the new background. Many moving targets are wrongly detected during this period of time which still needs further improvement.

To solve these problems, we propose an improved ViBe algorithm to accelerate the compute speed and increase the adaptive ability when facing the scene switching. The new algorithm uses a switch variable to control the model updating which can save some time. In addition, the improved ViBe add a part of detection of the scene switching based on the original ViBe. Once finding the switching, a fast model updating strategy would be used.

3.1. Switch Variable For Controlling the Updating Rate

According to the analysis before, upon a pixel being considered as background, there is a possibility of φ^{-1} to update the collection it correspond to. Actually when detecting the fire smoke in the forest, the background has little chance to change a lot in a second which contains a few frames. So it's not necessary to update the model for every frame.

A switch variable γ is presented. While $\gamma=0$, only the moving target detection will be done. When $\gamma=1$, both moving target detection and the model updating work will be done. γ would be set equaling to 1 when odd frames. In contrast, $\gamma=0$ when even frames. That is to say the updating work would be done every 2 frames which can save time.

3.2. Scene Switch Detection and Fast Model Updating

In the forest fire smoke detection system, after monitoring for a while, the camera would change the angle, which leads to the totally change of the background. The initial ViBe algorithm always takes a long period of time to update the model to adapt the changing.

If equation (3) is satisfied, it is believed that the scene is switching. ε refers to the number of pixels that are considered as moving target. X is the width of the image and Y is the height of the image. T is the threshold of the size of the moving target.

$$\varepsilon(X * Y)^{-1} > T \quad (3)$$

Once finding the scene switching, there are 2 strategies that could follow:

(1) Abandon the original model entirely and reinitiate the model. Several new frames would be used to initiate the model again as it said in chapter 2.

(2) Applying a faster updating strategy to the original model. It means the model would be updated rapidly by setting the updating rate smaller. For example, we always set $\varphi = 16$, but if the scene switching is detected, φ would be turned to 5. In fact, increasing the speed by modifying the parameter is more suitable for the video processing.

To summarize, the improved ViBe uses the first frame to initiate the background model and then do the foreground detection. A switch variable is used to control the updating rate and upon the condition change is detected; a faster updating strategy would apply to accelerate the speed.

4. Experiment

The experiments are done from 2 aspects to test the speed and the adaptive ability of the algorithm.

4.1. Experiments for Speed

We keep it in same condition to compare the speed of the GMM, Optical Flow Method, original ViBe and improved Vibe applied to moving target detection in forest fire smoke detection system. The hardware and software condition are listed in Table 1.

Table 1. Test Condition

Hardware Condition	CPU	Intel i5-3470
	Memory	4GB
Software Condition	Operating System	Windows 7 32bit
	IDE	VS2013
	OpenCV Version	2.4.G

The improved Vibe algorithm takes less time to detect the moving target in each frame, while other methods take more, as it showed in Table 2.

Table 2. Consumed Time of the Different Methods

Moving Target Detection Method	Time Consuming (ms/frame)
Optical Flow Method	107.274
GMM	93.441
ViBe	70.233
Improved ViBe	62.454

4.2 Experiments for Adaptive Ability

The improved ViBe algorithm also aims to increase the robustness when facing the scene switching. The time and number of frames are tested to see if the improved method does working. We compared our improved ViBe algorithm to GMM and the original ViBe algorithm. We can see the result in Table3. The improved ViBe took the least number of frames and time to adapt the scene switching.

Table 3. Adaptive Ability of Different Methods

Moving Target Detection Method	Number of frames to adapt the scene switching	Time to adapt the scene switching /s
GMM	182	17.006
ViBe	178	12.618
Improved ViBe	151	9.431

We the improved ViBe algorithm in different condition to see if it can detect the smoke successfully.



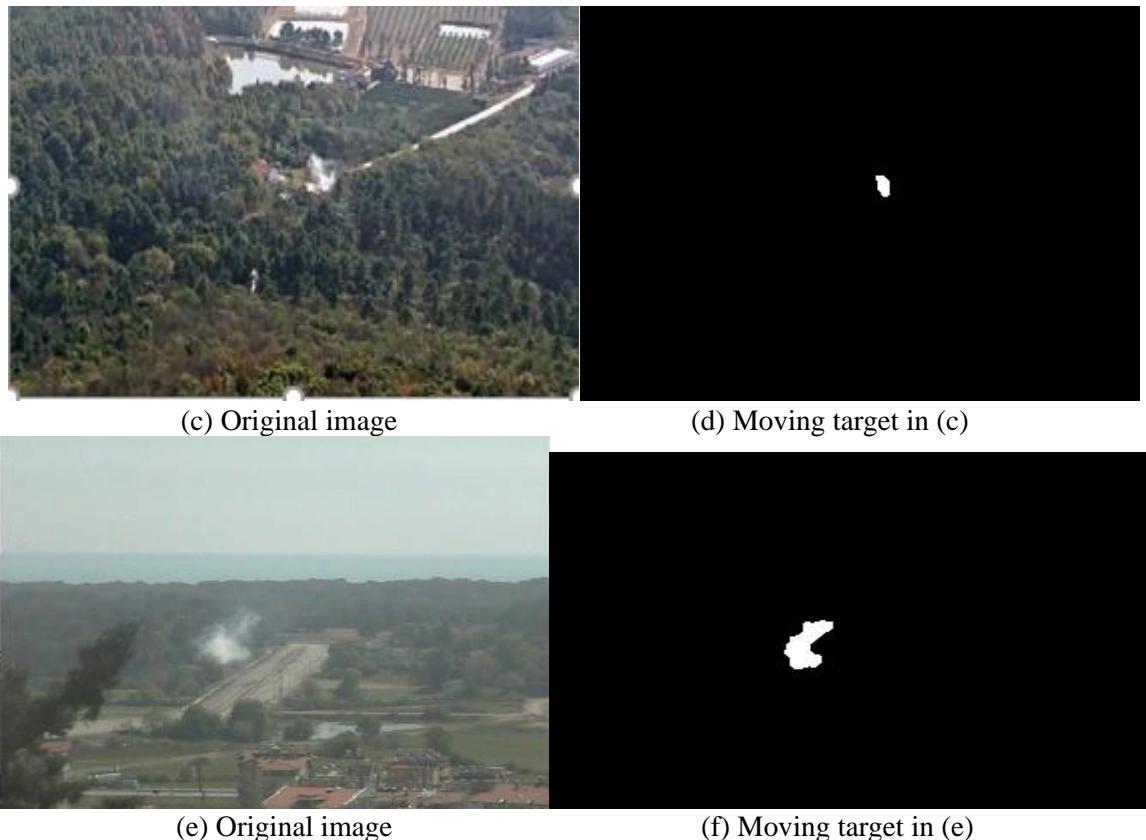


Figure 2. Moving object detection in different conditions

As it shows in Figure 2, our improved ViBe can find the smoke accurately in different conditions.

5. Conclusion

This paper proposes an improved ViBe algorithm which can better applied to the forest fire smoke recognition. The new algorithm introduces a switch variable to control the model update every 2 frames which can save the compute time. Also, the improved ViBe has strong adaptive ability when facing the scene switching. It contains a method to detect if the scene is switching or and once the switching is detected, a fast updating strategy will be carried out. In the future, more research would be done for the forest fire smoke detection at night, according to our algorithm is more suitable during the day.

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