Real Time Video Based-Early Fire Smoke Detection for Outdoor Environment

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***Abstract* - In life, fire accidents are always the one of causes of the great damages including human and production. Early fire smoke detection can help to alert and prevent disasters that generates great economic damages and human losses. In this paper we would like to propose a method to early detect both fire and smoke using video sequences captured by a single camera. The proposed method is based on the static and dynamic features of fire/smoke in the temporal and spatial domains as color feature, slow motion and growth to recognize and detect fire/smoke in the outdoor environment. Experimental results with video sequences captured by a single camera proved that the proposed method could recognize and detect fire/smoke in the outdoor environment. The performance of the proposed method is more exactly than some previous methods.**

***Index Terms*: Fire Smoke Detection, Motion Detection, Feature of Fire and Smoke, Video Processing.**

I. INTRODUCTION

Fire is a very important factor in human life but it also causes great harm to human. Fire accidents can occur everywhere without any prediction while the cause of fire accidents was very simple. They frequently cause great damages affected to human and economic. Therefore, an early fire smoke detection solution is necessary to prevent fire smoke disaster.

In order to avoid fire/smoke disasters, many early fire detection techniques have been extensively researched [1-3]. Overview, the current fire smoke detection techniques used many the connected smoke sensors in a system but they are very weak to early detect fire smoke in a wide area and the response of these systems is also very low. So, these systems are only useful for the indoor environment as buildings, home, offices and basements. They could not be applied to the outdoor environment. Because the outdoor environment as forest, street, the outside of factories or seaports could not setup a grid of the connected smoke sensors. However, we can use a single camera to monitor wide areas. So, a solution to early detection fire smoke in real time video sequences captured by a single camera is possible and suitable for the outdoor environment.

Previously, there are some proposed methods to detect fire flame or smoke based on image processing [4-7]. Horng et al. [4] presented a method to detect fire flame based on color analysis. The risk of this method is only to detect big fire flames in some special areas. It could not detect smoke. Ali et al. [5] introduced an algorithm to detect fire and smoke using the Wavelet analysis and disorder characteristics in the frequency domain. This method is very weak. Because authors did not described their method in detail. Moreover, this method did not also show experimental results in detail. Poobalan et al. [6] described a method to detect fire using image processing techniques. This method is better than previous methods but the analysis and experimental results of this method is still poor. This method could not also detect smoke. Khan et al. [7] proposed a fire/flame detection method based on color analysis of fire image. Fire images are converted into HSI color model and then the color mask is created and applied on the original image to detect the fire/flame regions. This method can only detect fire region and not detect smoke.

To respond to above risks, we would like to propose a method to early detect both fire and smoke using real-time video sequences captured by a single camera. The proposed method includes two parts: fire detection and smoke detection. The proposed method is based on the static and dynamic features of fire/smoke in the temporal and spatial domains to detect fire/smoke in the outdoor environment. The proposed method is described in Sec. 2. Experimental results and the evaluation of the proposed method will be explained in Sec. 3. The conclusion is discussed in Sec. 4.

II. THE PROPOSED METHOD

A. *Overview*

The proposed method is described in Fig. 1a. A single camera is setup to monitor wide areas as forest, street. The proposed method includes two parts: fire detection and smoke detection. Video is the input of fire detection and smoke detection. After the fire and smoke detection processes, system will check fire or smoke exist or not exist to give alarm. The detail of each part will be shown in next sub-sections.

B. *Fire Detection Algorithm*

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Fire detection algorithm is shown in Fig. 1b. Firstly, we based on the flicker of fire to detect motions in video input. Motion detection is the conventional work and it is very simple [8]. Thus, we will not explain it here. However, there are motions not fire objects. So, we need to remove non fire-color pixels by the fire-color pixels detection. Assume that $p_{x,y}$ is the moving pixel at the spatial location (x, y) in a frame after the motion detection step. Based on the observation of a large number of test frames, a pixel at the spatial location (x, y) in a frame is detected as the fire pixel if it satisfies conditions in Eq. (1) with *R*, *G*, *B* is Red, Green and Blue channels of the moving pixel $p_{x,y}$; R_T, G_T, B_T are thresholds of *R*, *G* and *B*. *I* and I_T are the intensity of the pixel $p_{x,y}$ and thresholds R_T, G_T, B_T respectively. After the fire-color pixels step, we count the number of frames that contains fire-color pixels. If there are 15 consecutive frames contained fire-color pixels, we will cluster fire pixels in blobs. Otherwise, we continue the motion detection step. Due to the fact that there are some similar fire objects as car light that can be existed in video, we need to count the number of occurrences of fire blobs to determine them be fire or not. This is also useful to remove fire objects which have a short lifetime. In the proposed method, we counted over 5 times to extract fire objects as described in Fig. 1b.

$$\begin{cases} R_{p_{x,y}} \geq G_{p_{x,y}} > B_{p_{x,y}} \\ R_{p_{x,y}} > R_T;\ G_{p_{x,y}} > G_T; \text{and } B_{p_{x,y}} < B_T \\ I_{p_{x,y}} \geq (255 - R_{p_{x,y}}) \times \dfrac{I_T}{R_T} \end{cases} \quad (1)$$

$$I_{p_{x,y}} = \frac{R_{p_{x,y}} + G_{p_{x,y}} + B_{p_{x,y}}}{3} \quad (2)$$

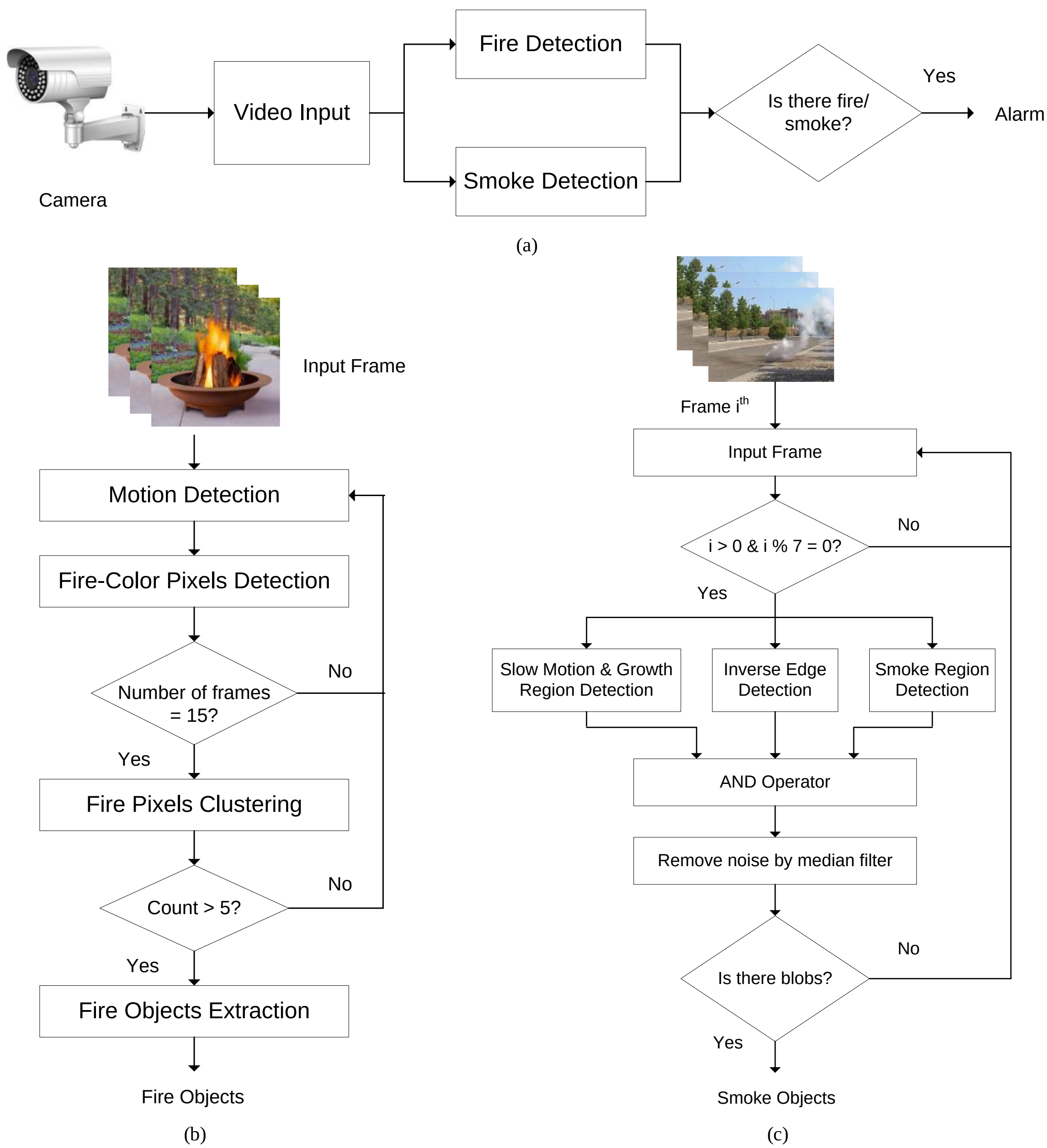

Figure 1. The proposed method, (a) Overview method, (b) Fire detection algorithm, and (c) Smoke detection algorithm.

Figure 2. Experimental Results.

C. *Smoke Detection Algorithm*

Smoke detection algorithm is shown in Fig. 1c. The proposed algorithm is based on the slow motion growth region of smoke, and color analysis. Firstly, after each 7 consecutive frames (see Fig. 1c) we detect slow motion and growth region by the subtraction method. We then add six frames which are obtained from 7 consecutive frames to get the slow motion in a total frame. The purpose of this step is to remove fast motion and get smoke region candidates. Given $\mathrm{I}_i, \mathrm{I}_i^S, \mathrm{M}_I$ are the current frame, the subtracted frame, and the image after the slow motion and growth detection step respectively. They are obtained as shown in Eq. (3) and (4).

$$\mathrm{I}_j^S = |\mathrm{I}_i - \mathrm{I}_{i-1}| \quad i = 2, 3, \ldots \mathrm{N};\ 1 \leq j \leq 6 \tag{3}$$

$$\mathrm{M}_I = \sum_{j=1}^{6} \mathrm{I}_j^S \tag{4}$$

Due to the fact that the edge region of smoke regions is redundancy, unnecessary and some objects as cloud or the thin smoke of cars can be detected as smoke regions, we need to remove them. To remove this object, we filter the current frame I_i by the Sobel filter and then reverse the edge image to get the inverse edge image E_i^I as shown in Eq. (5).

$$\mathrm{E}_i^I = Reverse(Sobel(\mathrm{I}_i)) \tag{5}$$

Next, we detect regions in the current frame I_i where they are considered as smoke candidates. This work is implemented based on the color features of smoke. The pixel $p_{x,y}$ at the spatial location (x, y) in the frame I_i is considered as smoke pixel if:

$$100 \leq F_{p(x,y)} \leq 240 \tag{6}$$

After the smoke regions detection, we have the smoke candidate image C_i^I. We able to detect smoke regions by the AND processing of three images obtained from slow motion & growth detection, inverse edge detection and color feature processing as described in Eq. (7). Finally, small noise elements and small smoke candidates will be remove by the median filtering process to extract smoke objects as shown in Eq. (8).

$$\mathrm{S}_I = AND\{\mathrm{M}_I; \mathrm{E}_i^I; \mathrm{C}_i^I\} \tag{7}$$

$$\mathrm{S}_I^{final} = Median\ Filter(\mathrm{S}_I) \tag{8}$$

IV. EXPERIMENTAL RESULTS

We implemented and experimented the proposed method on a computer with Window 7/64-bits, Core i7/3.5–GHz, 8 GB of RAM, and implemented by using Visual Studio C++ 2015 and the image processing library Open CV 2.4.11. We used sequence videos captured by a single camera that is set to capture and record test videos from different areas as forest, street, parking and the outside of house [9, 10]. Thresholds in Eq. (1) are determined based on the color information of fire and smoke [11], and the pixel value of smoke is determined based on smoke's feature [12]. With $R_T = 190, G_T = 100, B_T = 140$, and $I_T = (R_T + G_T + B_T)/3$.

Table 1. Experimental Results.

Video	Size	Frame Rate	Total Frame	Accuracy (%)
Smoke 1	320x240	25	2200	98.3
Smoke 2	320x240	25	3005	98.7
Smoke 3	320x240	25	1835	98.1
Smoke 4	320x240	25	2345	98.5
Smoke 5	320x240	25	2024	98.8
Smoke 6	320x240	25	2151	99.0
Fire Smoke 1	400×256	15	255	97.6
Fire Smoke 2	400×256	15	240	98.0
Fire Smoke 3	400×256	15	195	96.3
Fire Smoke 4	320×240	10	1200	95.0
Fire Smoke 5	400×256	15	210	97.0
Fire Smoke 6	400×256	15	210	97.0

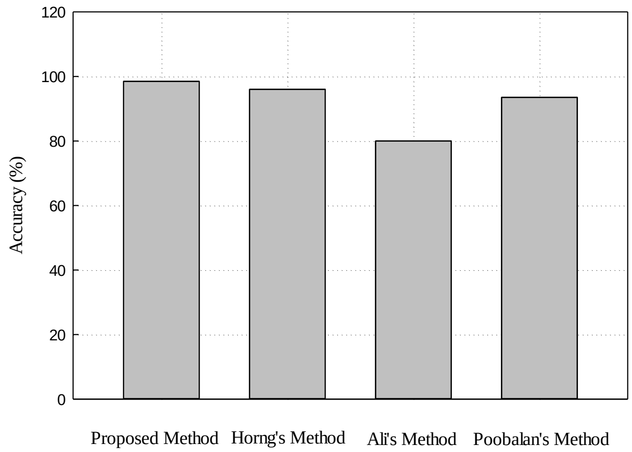

Figure 3. Accuracy comparison between methods.

Test sequence videos contain only smoke or contain both fire and smoke. The detailed information of test videos is shown in Tab. 1. Based on Fig. 2, we concluded that although the size and frame rate of test videos are different but the proposed method detected both fire and smoke well. The proposed method can detect fire/smoke in near outdoor environments as street, parking or far outdoor environment as forest. To compare the proposed method to previous proposed methods, we compare the accuracy between methods. The accuracy of the proposed method is calculated as shown in Eq. (9) with N_T is the number of true detections in a test video and N_S is the number of total detections in a test video.

$$Accuracy = \frac{N_T}{N_S} \tag{9}$$

Based on Tab. 1, we concluded that the accuracy of the proposed method is dependent on the frame rate of videos. If the frame rate is high (25~30 frames/s), the accuracy of the proposed method will be high and otherwise. In Horng's method [4], the average accuracy is 96.73%. The accuracy of Ali's method [5] is 80%, and in Poobalan's method [6] the accuracy is 93.61%. In Khan's method [7], the accuracy is not show. In our method, the average accuracy is greater than 98%. This means the accuracy of the proposed method is higher than the accuracy of previous methods as shown in Fig. 3.

V. CONCLUSION

In this paper, we proposed, implemented and experimented an algorithm for fire/smoke detection system based on image processing using a single camera. The proposed method is implemented on both computer with USB-Camera and IP Camera. Experimental results proved that the proposed method detected fire and smoke in almost cases. The accuracy of the proposed method is better than the accuracy of previous methods. The proposed system can implement for the outdoor environment as forest, parking, sea-port/habor and so on. Future, we will implement and experiment with the large size of videos and multi-IP Cameras to evaluate the accuracy of the proposed method in real-time.

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