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Vision-Based Smoke Detection Algorithm for Early Fire Recognition in Digital Video Recording System

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***Abstract*— The *digital video recording* (DVR) *closed circuit television* (CCTV) system is quickly becoming one of the most accepted security, surveillance documentation, and monitoring in service today. Particularly a lot of catastrophes such as tsunami, volcano, and terrorism cause huge casualty and property loss. In this paper, we concentrate on the smoke detection system in video for early fire alarming. The proposed block-based smoke detection algorithm consists of three basic steps, which has simple operation and provides good performance. In the first step, we discover motion vector utilizing several motion estimation schemes and discern the suspect as smoke region. This process does not require huge computational cost because of using the H.264/AVC during the recoding in DVR system. In the second step, we conduct block based chromatic detection. In the third step, we employ motion information for detecting the correct smoke block by using the characteristics that smoke goes almost upward. Experimental results provide that the proposed method gives good performance for real smoke detection.**

Keywords - smoke detection in video, DVR system, CCTV, motion estimation, motion detection

I. INTRODUCTION

Recent catastrophes such as explosion of The Fukushima I Nuclear Power Plant, massive tsunami, fire, flood, and avalanche have caused great number of serious casualty and huge property damages. Therefore, early alarming systems are requested to be studied. In particular, research on the automatic smoke detection for early fire recognition is widely studied recently. A smoke detector is a device that detects smoke, typically as an indicator of fire. Commercial, industrial, and mass residential devices issue a signal to a fire alarm system, while household detectors, known as smoke alarms, generally issue a local audible and/or visual alarm from the detector itself. Many conventional fire detectors are based on optical, ionization, particle sampling, temperature sampling, relative humidity sampling, and air transparency testing [1]. Those sensor-based smoke detection has been widely used because of low cost and simple set up. However, these systems do not work until the material contact the sensor and cannot know the additional information such as fire scale, location, and growing rate. Our purpose is to develop the digital video recording (DVR) system that is digital security system of next generation improving strong point and significantly complementing defects of existing analog CCTV is coming. Figure 1 shows general video-based disaster monitoring system with DVR that is the newest digital motion picture compression and powerful digital video security system using MPEG video codec like H.264/AVC and MPEG-x.

In recently years, many smoke detection techniques researched on video processing using camera. Toreyin et al. explained motion, flicker, edge blurring and color can be employed for determining the appearance of smoke [2], where motion can be detected by simple frame differences or background subtraction. Moreover, motion detection is able to eliminate the disturbance of stationary non-smoke objects. In [3], Chen et al. used RGB/HIS color model and studied dynamic analysis of flames that matches the disordered characteristic of flames with an increase of pixels to check for the existence of a fire. However, this system cannot discern flames from objects that appear red in color, and give a wrong fire alarm decision. Ho et al. proposed a real-time alarm system for detecting flames and smoke using their spectral, spatial, and temporal features [4]. The statistical distribution of the spectral and spatial probability density is weighted via fuzzy reasoning system to give potential flame and smoke candidate regions. In [5], Yuan used an accumulative motion model based on the integral image by fast estimating the motion orientation of smoke.

In this paper, we propose vision-based smoke detection algorithm for early fire recognition in digital video recording system. The paper is organized as follows. Section II describes in threefold: (1) moving block detection using motion vector where we assume the moving block as smoke candidate block, (2) smoke decision algorithms using block based chromatic detection, and (3) smoke decision using the upward characteristic. We conduct experiments with different motion estimation algorithms. Section III provides the experimental results and future work. Conclusion and final remarks of this paper is described in Section IV.

II. BLOCK-BASED SMOKE DETECTION

A. Moving Detction using Motion Estimation

Many motion estimation and motion detection algorithms are studied and presented in literature. For example, optical flow, background subtraction, and frame difference are exiting methods for moving detection. In this paper, we chose the block matching motion estimation algorithm for smoke detection of early fire recognition system. Our proposed method is not complex because block matching motion estimation is conducted in DVR system. Therefore we just use

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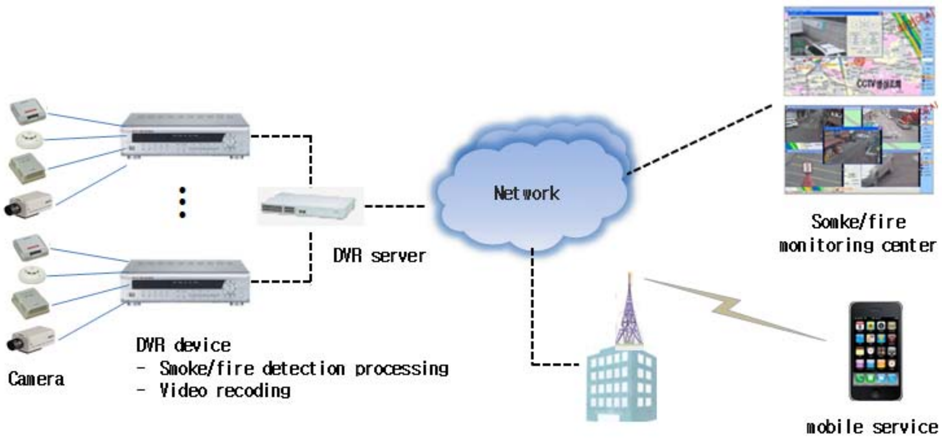
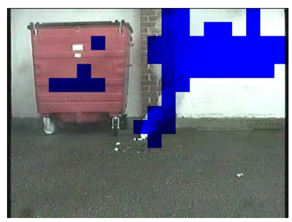


Figure 1. General video based disaster monitoring system.

(a)



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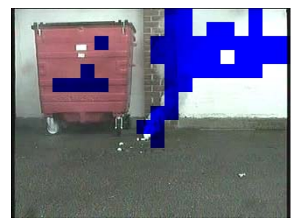
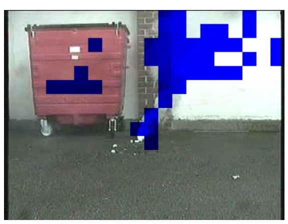
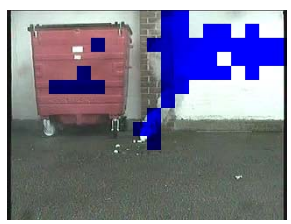


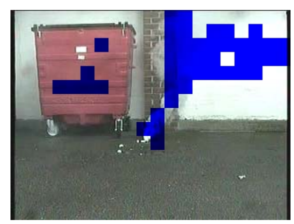
(c)



(d)



(e)



(f)

Figure 2. Moving detection results by various motion estimation algorithms. (a) Original frame, (b) FS, (c) TSS, (d) SETSS, (e) NTSS, and (f) DS.

motion information which is already computed during the video record processing. The video codec used in DVR can be MPEG-x or H.264/AVC.

A number of fast or efficient motion estimation algorithms have been researched. Followings are brief introduction of some conventional block based motion estimation algorithms. By exhaustively testing all the candidate blocks within the search window, full search (FS) algorithm determines the global optimum solution to the motion estimation. However, FS demands a substantial amount of computational load. To overcome this drawback, many efficient block-matching algorithms have been developed. For example, three-step search (TSS) [6], simple and efficient three-step search (SETSS) [7], new three-step search (NTSS) [8], and diamond search (DS) [9] are known.

These methods produce the motion information which is represented as motion vector (MV). It is good to find motion region with motion activity (Φ). The activity of macro blocks (MBs) is defined as,

$$MV_{\Phi}^{MB} = \sqrt{\left(MV_{x}^{MB}\right)^{2} + \left(MV_{y}^{MB}\right)^{2}} \quad (1)$$

where MV_{x}^{MB} and MV_{y}^{MB} are motion vector in each macro block, x and y are macro block position.

The moving region decision (MRD) is determined as

$$MRD^{MB} = \begin{cases} 1, & if\left(MV_{\Phi}^{MB} > \tau_{1}\right) \\ 0, & otherwise \end{cases} \quad (2)$$

where τ_1 is a predetermined threshold. Based on the motion activity, moving region decision is performed. If the block is determined as MRD, we further assume that the block is a possible smoke block and set to one. Otherwise, the block is set to zero.

Figure 2 shows the results that possible smoke block detection applied through various motion estimation methods. It is known that the FS algorithm shows the best performance, however other methods show very comparable performances in the smoke moving region. Our simulation needs simple and good performance to find the smoke region. Therefore, we can adopt the other fast motion estimation algorithms too. We selected SETSS method in this paper for its speed and simplicity.

B. Smoke Decision using Chroma and Upword Characteristic

In the preceding section, we introduced a simple moving area detection scheme during the motion estimation processing in DVR system. In this section, we further study how to correctly detect the smoke region for early fire alarming. And then we reflect the smoke characteristic in decision process.

1) Chroma decision on the smoke candidate blocks

The smoke usually shows the grayish colors during the burning materials. There are two gray level regions such as *light gray* and *dark gray*. The possible color range of smoke block in the RGB color space is introduced in [3, 5]. As we know, video images usually have a great amount of noises due to intrinsic electronic noises and quantification in the pixel by pixel processing. To reduce noises, we firstly add up the values of each color channel components (c_Ω) within a block (C_Ω^{MB}), as in

$$C_\Omega^{MB} = \sum_{(x,y)\in MB} c_\Omega(x,y) \tag{3}$$

where Ω={R,G,B}, and C_Ω^{MB} is sum of each Ω color in block.

In these smoke colors, R, G, B components of the blocks are very close to each other. In other words, the absolute difference of the maximum and minimum values among the three components should be less than a predetermined threshold τ_2. The intensity (I) is also smoke pixel which is ranging from τ_3 to τ_4.

$$C_{\max}^{MB} = \max\left(\frac{C_R^{MB}}{s^2}, \frac{C_G^{MB}}{s^2}, \frac{C_B^{MB}}{s^2}\right) \tag{4}$$

$$C_{\min}^{MB} = \min\left(\frac{C_R^{MB}}{s^2}, \frac{C_G^{MB}}{s^2}, \frac{C_B^{MB}}{s^2}\right) \tag{5}$$

where s is macro-block size and s^2 is normalized factor. The max(·) and min(·) are maximum and minimum operations in elements.

2) Motion-direction decision on the smoke candidate blocks

The smoke is usually continuously drifting upwards because of hot airflow [5]. Based on this characteristic, we apply this to find the moving blocks. Firstly, we find motion direction (Ψ) as

$$MV_\Psi^{MB} = \arctan^{-1}\left(\frac{MV_y^{MB}}{MV_x^{MB}}\right) \tag{6}$$

where again MV_x^{MB} and MV_y^{MB} are motion vector in each macro block. The threshold τ_5 is determined empirically. As previously stated, all parameters have been computed in the previous steps.

3) Smoke decision on the smoke candidate blocks

The aforementioned *chroma decision* and *motion-direction decision* rules are used for more accurate smoke block decision from moving detection step. After detecting moving blocks, we use two decision rules to discern smoke blocks.

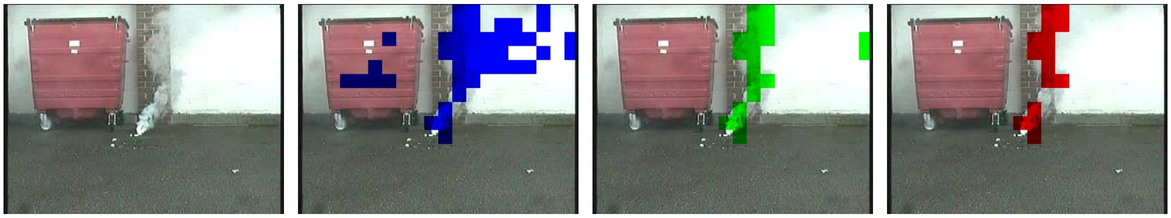
$$\begin{aligned}
&\text{Rule 1:}\\
&\qquad \left|C_{\max}^{MB} - C_{\min}^{MB}\right| < \tau_2\\
&\text{Rule 2:}\\
&\qquad \tau_3 < I < \tau_4\\
&\text{Rule 3:}\\
&\qquad MV_\Psi^{MB} > \tau_5
\end{aligned} \tag{7}$$

$$\begin{aligned}
&if\ \left(Rule\ 1\ \&\ Rule\ 2\ \&\ Rule\ 3\right)\\
&\qquad \text{region is } smoke\ block\\
&otherwise\\
&\qquad \text{region is } non-smoke\ block
\end{aligned} \tag{8}$$

III. Experimental Results

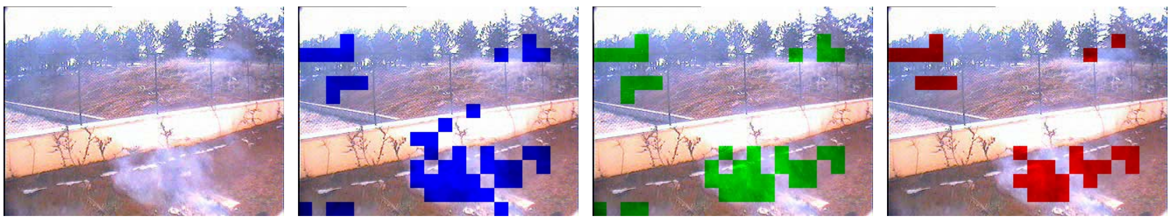
A. Performance Evaluation

The proposed block-based smoke detection algorithm performed on Intel core i5 processer with 4G RAM. Our algorithm was tested in several videos on the size of 320x240. Figures 3 and 4 show the results of our proposed method that are moving detection, chroma decision, and smoke decision. Figures 3(b) and 4(b) shows detected moving region obtained by SETSS motion estimation algorithm. As we can see, some of the moving blocks include non-smoke regions. Therefore, we have to apply the two more decision rules for determining more accurate smoke region. One is the chroma decision rule for eliminated the non-smoke blocks (results are shown in Figs. 3(c) and 4(c)). To improve the performance, we applied motion-direction decision because smoke almost drifts upwards. Obviously, the real smoke blocks are finally selected, as shown in Figs. 3(d) and 4(d).



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

Figure 3. Smoke decision results by chroma and upward characteristic (a) original frame, (b) moving detection, (c) chroma decision, (d) smoke decision.



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

Figure 4. Smoke decision results by chroma and upward characteristic (a) original frame, (b) moving detection, (c) chroma decision, (d) smoke decision.

For the bright background, the smoke blocks are correctly selected. However, the selected blocks may fail in the dark environment due to the camera's capturing attributes. Nevertheless, intra ray camera can be used to cope with the capturing problem inherently existed in the dark surroundings.

B. *Future Work*

In this paper, we used the characteristics that smoke usually drifts upwards. However, this model is insufficient in some specialized and rarely occurring cases where the turbulent smoke feature occurs. We will analyze the chaos feature and to overcome this drawback make use of support vector machine (SVM), fuzzy set theory, and other possible probability models.

IV. Conclusions

In this paper, we proposed a block based smoke detection method in image processing to provide an early fire alarm. Although, the moving regions are roughly estimated, the computation is efficient because this process does not require additional computations during the recoding in DVR system. Both chroma and motion-direction features of smoke region are used in the decision rules to improve the reliability of block based smoke detection.

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References

[1] T. Chen, C. Kao, and S. Chang, "An intelligent real-time fire-detection method based on video processing," in *Proc. the International Carnahan Conference on Security Technology*, pp. 104–111, Oct. 2003.

[2] B. Toreyin, Y. Dedeoglu, and A. Cetin, "Wavelet based real-time smoke detection in video," in *Proc. European Signal Process Conference, EUSIPCO2005*, 2005.

[3] T. Chen, Y. Yin, S. Huang, and Y. Yen, "The smoke detection for early fire-alarming system base on video processing," in *Proc. the International Intelligent Information Hiding and Multimedia Signal*, pp. 427–430, 2006.

[4] C. Ho, "Machine vision-based real-time early flame and smoke detection," *Measurement Science and Technology*, pp. 1–13, Jan. 2009.

[5] F. Yuan, "A fast accumulative motion orientation model based on integral image for video smoke detection," *Pattern Recogniton Letter*, vol. 29, no. 7, pp. 925-932, Jan. 2008.

[6] T. Kog, K. Iinuma, A. Hirano, and Y. Ishiguro, "Motion compensated interframe coding for video conference," in *Proc. the National Telecommunications Conference*, pp. G5.3.1-G5.3.5, Nov. 1981.

[7] J. Lu and M. L. Liou, "A simple and efficient search algorithm for block-matching motion estimation," *IEEE Transactions on. Circuits and Systems for Video Technology*, vol. 7, no. 2, pp. 429–433, Apr. 1997.

[8] R. Li, B. Zeng, and M. L. Liou, "A new three-step search algorithm for block motion estimation," *IEEE Transactions on. Circuits and Systems for Video Technology*, vol. 4, no. 4, pp. 438–442, Aug. 1994.

[9] S. Zhu and K. Ma, "A new diamond search algorithm for fast block-matching motion estimation," *IEEE Transactions on. Image Processing*, vol. 9, no. 2, pp. 287–290, Feb. 2000.