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Detection of Smoke Propagation Direction Using Color Video Sequences

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Abstract: To better assess fire location and direction of fire development, it is crucial to detect smoke and a clear undestanding of smoke propagation direction. Smokes tend to progress rather than backtrack. They do not usually go in one direction. The proposed method focuses on the detection of smoke propagation direction with image analysis that enables a potential fire risk situation to be recognized at an early stage. Using the consecutive smoke image frames having significant smoke candidate, comparison has been done by DP matching to detect the global direction of smoke propagation. In this research, the possible directions of smoke have been grouped into 4 categories. The direction of movement of smoke in one category shows the global direction of smoke propagation in that direction. The general information about that direction can be used to identify area at risk for at least filling with smoke and possibly catching fire.

Key words: Smoke detection, image processing, DP matching and histogram analysis

INTRODUCTION

Understanding smoke and its propagation in the bud can save crucial seconds that can often make the difference between life and death, or between mild structural consequences and complete collapse of the building. The use of early warning of fire and smoke detection systems has resulted in a significant reduction overall in fire deaths. The sooner a fire is detected, the better the chances are for survival. To identify how fires develop, smoke detection and its spreading style analysis is an important part of safety analysis and is essential in assessing the risk of escalation.

Smokes develop in different ways and are often unpredictable in their growth. Smoke has multispectral signatures such as color, geometry and motion. The shape of a smoke region usually keeps changing which depends on surrounding environmental factors. The proposed research is aimed at cost-effective and accurate means of designing efficient smoke propagation direction detection system with color video scene analysis.

Background: There are some papers about fire and smoke detection using image analysis and only a few papers concentrate on smoke propagation. Smoke usually complements with fire nearby. Hence to detect smoke and its propagation style, attention has been paid also on fire detection with vision algorithm. Existing methods of visual fire detection rely almost exclusively upon spectral analysis except (Rubaiyat *et al*., 2005). Some systems use CCD cameras (Chen *et al*., 1999). The methods described in Kozeki (1999) and Kozeki (2001) uses an infrared and thermo-graphic cameras.

The vision-based methods presented in Healey *et al*. (1993) and Foo (1995) to detect fire seem to be promising. The system reported in Plumb *et al*. (1996) makes use of specialized point-based thermal sensors with thermal camera. However, none of them address the detection of smoke and rely upon ideal conditions. The method used in Rubaiyat *et al*. (2005) is based on image analysis of the smoke scenes captured by a normal video camera with detection algorithms; it can detect smoke from the taken images in its early stage.

Although, there are some methods to detect smoke propagation direction, almost no effort has been paid to detect the direction of smoke propagation with image analysis. Choi *et al*. (2005) shows the variation of smoke propagation distance with different parameters such as fire size, ventilation rate in a tunnel. In the study Chen *et al*. (2003), authors computed the 3-dimensional smoke flow fields to understand the mechanisms driving the motion of smoke and stack effect.

None of the papers address the image-based smoke propagation detection and its fashion. Hence a vision based smoke propagation detection system with color video scenes has been proposed here.

MATERIALS AND METHODS

The proposed research comprising use of surveillance camera means, video frame comparison means and signal processing means. The method is arranged to analyze different frames acquired by the video camera monitoring means and to compare the intensity and/or color of individual pixels or group of pixels so as to consider the inter-relationships of these pixels to detect the presence of smoke characterized in that signal processing means.

In this proposed research, the smoke is assumed to be associated with fire. Hence after detecting fire with the help of Rubaiyat *et al*. (2005), smoke has been detected by Chen *et al*. (2003). If the smoke detection algorithm indicates a potential smoke condition then statistical analysis is supposed to be carried out to detect the direction of smoke propagation with statistical analysis by DP matching. Hence to get potential smoke candidates, the threshold based analysis is proposed to be operated by weighting each subblocked region, for example using a point count system to provide a pass/fail form of scoring. Generally the signal processing means provides one frame as a reference and compares the current frame with that reference. The image-based algorithm subtracts the reference frame when it is treated as background. The block diagram of the proposed method is shown in Fig. 1.

After detecting smoke, main focus is on detecting its propagation path. A step by step procedural diagram has been shown in Fig. 2. Here subblocking has been done on the detected smoke images first. Then the smoke count is calculated in every subblock of the image. If the smoke count of a subblock is greater than a threshold, the whole subbolck is considered as smoke candidate. Then binarization has been done here by putting "1" in the subblock and the other subblocks whose smoke count is less than the threshold value, "0" has been putted there. After getting the binarized subblock of smoke candidate, contours of smoke images has been calculated. Then comparing the contours of successive smoke images, DP matching has been applied to calculate the displacement vector from 2 successive images.

The concept of DP matching is as follows. Two successive frames are considered as set of pixels. The elements of each set are the contour pixels of its subblocked binarized smoke images shown as follows:

$$A = \{a_1, a_2, a_3, a_4 \text{------------------} a_n\},$$
$$B = \{b_1, b_2, b_3, b_4 \text{------------------} b_n\}$$

Let us consider, A be the set of contour pixels for ith frame and B for $(i + 1)^{th}$ frame. Then for one element of A, it searches every element of B for matching with its minimum cost by heuristic search method. The process is repeated for all the element of A. By matching the every elements of A with B, it gets the displacement vector for 2 successive frames. Then all the displacement vectors are plotted for histogram analysis to get the peak of displacement vectors number with respect to orientation. After getting the peak, it is considered that the orientation corresponding to the peak of displacement vector to be the global direction of smoke for those two image frames. Rather than considering two successive frames only, this idea can be used for comparing any two image frames with periodic appearance.

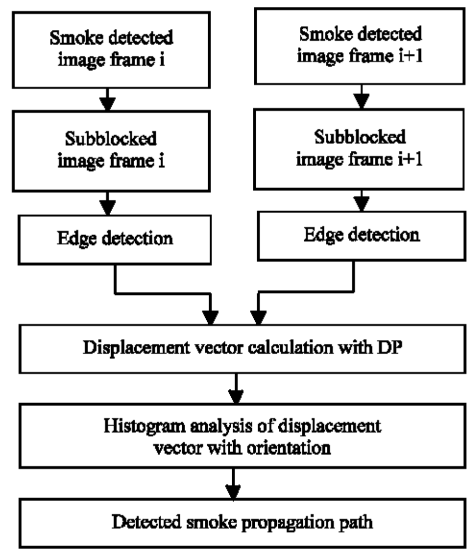

Fig. 1: Smoke propagation path detection algorithm

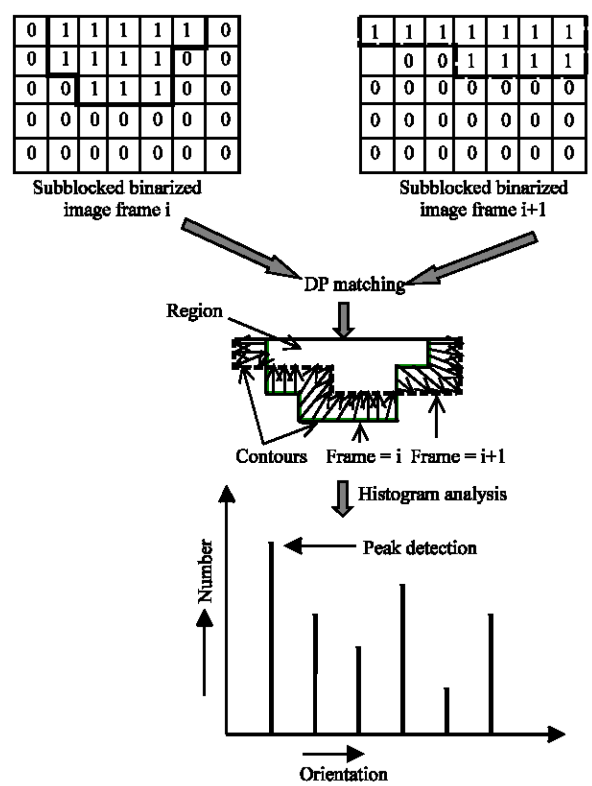

Fig. 2: Procedural steps for detection of global smoke direction

RESULTS AND DISCUSSION

A video sequence of smoke has been taken within a closed room using a video camera. The size of the room was about 25×25 square feet. The real smoke had been generated by burning small pieces of woods with some burning chemicals. The camera was positioned about 10 feet far from the smoke occurrence spot. The collected video sequence has been converted to a number of corresponding color image frames. The video sequence consists of 13,000 frames in BMP file with resolution of 720×480 pixels. The various fashions of smoke have been observed from the start of burning to the end to detect the various global direction of smoke using vision algorithm.

To detect the global direction of smoke from color image frames shown in Fig. 3 and 4, the detected binarized smoke image has been subblocked which is shown in Fig. 5 and 6, respectively. To detect the global direction of smoke propagation, rather than considering all the directions the directions of smoke propagation has been grouped into 4 over all directions as, 0-45, 45-90, 90-135 and 135-180°.

The consecutive frames do not show the change of global direction of smoke. Hence, observation has been done on the detection of the global direction of smoke after every 10 frames. Displacement vectors have been calculated for image frame 1800 and 1810 which is shown in the Table 1. To show the validity of wide range of

Fig. 3: Original image frame 1800

Fig. 4: Original image frame 1810

image frames, the same calculations have been done for various image frames and the results are shown in Table 2-5. It is observed from Fig. 7 that most of the Displacement Vectors from the edge of smoke image frame 1800 to the edge of smoke image frame 1810 orient towards 0-45°. Hence the histogram analysis of Displacement Vector orientation of smoke is maximum towards 0-45° group. Then it has been considered that this direction of maximum Displacement Vector orientation to be the direction of propagation of smoke. Therefore, we can say that the global direction of smoke for these 2 image sequences is 0-45°.

Again, Table 2 shows the displacement vectors of smoke from 1810-1820. Here maximum number of Displacement Vectors orient around 135-180° for these two successive frames. Hence, the global direction of smoke here is toward 135-180°. Therefore, from the observation after 10 frames in Table 1-5, it could be said that the smoke propagates in 2 overall directions from 1800-1850 frame.

Table 1: The displacement vector from smoke image sequences 1800 and 1810

Orientation of displacement vector	Number of displacement vector
0-45°	9
45-90°	1
90-135°	6
135-180°	5

Table 2: The displacement vector from smoke image sequences 1810 and 1820

Orientation of displacement vector	Number of displacement vector
0-45°	3
45-90°	1
90-135°	2
135-180°	5

Table 3: The displacement vector from smoke image sequences 1820 and 1830

Orientation of displacement vector	Number of displacement vector
0-45°	8
45-90°	2
90-135°	5
135-180°	5

Table 4: The displacement vector from smoke image sequences 1830 and 1840

Orientation of displacement vector	Number of displacement vector
0-45°	9
45-90°	0
90-135°	5
135-180°	4

Table 5: The displacement vector from smoke image sequences 1840 and 1850

Orientation of displacement vector	Number of displacement vector
0-45°	9
45-90°	0
90-135°	4
135-180°	3

Fig. 5: Subblocked smoke image frame 1800

Fig. 6: Subblocked smoke image frame 1810

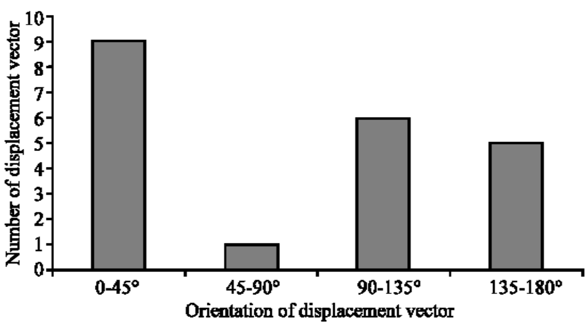

Fig. 7: Histogram of displacement vector from image frame 1800-1810

CONCLUSION

Detection of global direction of the detected smoke was observed for a range of image sequences. Our algorithm gives a clear understanding about the propagation path of smoke. This method of smoke propagation direction provides unique information about the spreading style of smoke in a fire caught place. Observation has been done here assuming the smoke to be whitish, further work can be done considering blackish smoke. The effect of air flow can also be considered in future.

REFERENCES

Chen, F., S.W. Chien, H.M. Jang and W.J. Chang, 2003. Stack effects on smoke propagation in subway stations. Continuum Mechanics and Thermodynamics J., 15 (5): 425-440. DOI: 10.1007/s00161-003-0117-5.

Chen, X., J. Wu, X. Yuan and H. Zhou, 1999. Principles for a video fire detection system, university of science and technology of China, People's Republic of China. Fire Safety J., 33 (1): 57-69. DOI: 10.1016/S0379-112(98)00047-2.

Choi, J.S., M.B. Kim and D.H. Choi, 2005. Experimental investigation on smoke propagation in a transversely ventilated tunnel. J. Fire Sci., 23 (6): 469-483. DOI: 10.1177/0734904105052553.

Foo, S.Y., 1995. A rule-based machine vision system for fire detection in aircraft dry bays and engine compartments. Knowledge-Based Syst., 9: 531-540. DOI: 10.1016/S0950-7051(96)00005-6.

Healey, G., D. Slater, T. Lin, B. Drda and D. Goedeke, 1993. A system for real-time fire detection. In Computer Vision and Pattern Recognition. Proceedings CVPR, pp: 605-606. DOI: 10.1109/CVPR.1993.341064.

Kozeki, D., 2001. Smoldering Fire Detection by Image-processing. Conference on Automatic Fire Detection, AUBE. www.fire.nist.gov/bfrlpubs/fire01/PDF/f01082.pdf.

Kozeki, D., 1999. Observation of Early Stage Fires by a Multi Spectrum Camera. Proceedings of AUBE, pp: 180-186.

Plumb, O.A. and R.F. Richards, 1996. Development of an Economical Video Based Fire Detection and Location System, US Dept. of Commerce, Technology Administration, National Institute of Standards and Technology. http://www.fire.nist.gov/bfrlpubs/fire96/PDF/f96005.pdf.

Rubaiyat, Y., M.M. Hossain and M.A.F.M.R. Hasan, 2005. Image based fire detection from color video fire scenes. J. Bangladesh Elec. Soc., 5 (2): 129-134.