# Early Fire Detection in Coalmine Based on Video Processing

Wanzhong Lei[1] and Jingbo Liu[2]

[1] Department of Electrical Information Engineering Henan Institute of Engineering, Zhengzhou, 451191, China
zzlwz@163.com
[2] School of Electrical Engineering
Southwest Jiaotong University
Chengdu, 610031, China
ljb79@126.com

**Abstract.** Fire is one of the most serious catastrophic disasters in the coalmine. The early fire detection can help to avoid a disastrous fire. The existing temperature-sensed and smoke-sensed method may respond slowly to early fire, if it is far away from the sensors, or the setting values of sensor are unsuitable. Therefore, the detection method based on image and video processing is adopted to overcome the drawbacks of traditional fire detection method for coalmine. The paper analyses the status in the fire detection technology, and designs a structure to detect the early fire in coalmine. Firstly, image which comprises the potential fire region the potential fire region is detected by using frame differencing of monitor video, and denoised by median filter. Secondly, flame region is extracted by color information. Finally, Bayes classifier is employed to recognize fire combined with the dynamic features. The method can greatly improve accuracy of early fire prediction in coalmine, comparing with the traditional detection method.

**Keywords:** Video processing, Image processing, Fire detection, Coalmine, Flame recognition.

## 1 Introduction

Fire is one of the most serious catastrophic disasters in coalmine and it usually influences the safety production severely. It not only results in huge economy loss, but also threatens on miner security. If the fire can be warned by alarm early and be eliminated in time, the harm should be reduced greatly. Therefore, real-time fire detection is significant, especially in coalmine. There are some fire detection methods, such as the temperature induction, the smoke induction, the light induction and the complex pattern. In practice, these traditional methods may make leak forecast or wrong forecast in abominable condition for environmental disturbance, also cannot respond to the early fire timely. It is generally known that the environment of coalmine is very complex; thus, need to find new method to detect the early fire in coalmine.

The flame has abundant vision information, such as geometry parameters, luminance parameters, and flicker frequency. To overcome the previous problems

G. Yang (Ed.): Proceedings of the ICCEAE2012, AISC 181, pp. 239–245.
springerlink.com 

mentioned above, the image-based fire detection technology has been proposed based on the advantages of the image processing in recent years. Healey [1] use a model based on color information of fire while Phillips [2] further adds the time-varying property of the flame color in the detection process thus to reduce affection of background illumination. In [3], boundaries of flames are represented in wavelet domain and high frequency character of the fire region' boundaries is used as the fire detection feature. Other researchers use multiple features of flame to perform better. Liu et al. [4] detect the top point across the frame edge by using the FFT algorithm. Chen et al. [5] develop a set of rules over the RGB color space to detect the fire pixels. Marbach et al. [6] exploit a YUV-based color model to represent the fire in video data. Motion detection on the Y channel is used to detect the candidate fire pixels. The detected pixels are then verified based on their chrominance information U and V to determine whether the candidate pixels are the fire pixels or not. Horng et al. [7] develop an HSI-based color model to segment the fire-like regions for brighter and darker environments. Their fixed threshold method achieves 96.94% detection rate. It is expected that a large amount illumination variations is quite likely incurred during the incidence of fire. In [8], an alternative approach in color-based detection is to analyze the YCbCr color space instead of the RGB space, a fuzzy logic approach, which uses luminance and chrominance information, is used to replace the existing heuristic rules used to generate the potential fire region.

Although some problems and drawbacks still exist in the above systems, image-based technology has many advantages comparing with traditional technologies. It has a very good detection rate, can provide intuitionistic fire image information, and can be used in large space and abominable environment, so it is suit to early fire detection in coalmine. The method proposed in paper adopts [8] to detect the early fire in monitor videos of coalmine. It has many important military and commercial applications and has significant advantages over traditional fire detection methods. To avoid leading to a fire disaster, the fire alarm should be given as soon as detecting a burning fire early.

The rest of paper is organized as follows. In section 2, characteristics of fire used in paper are described. The proposed detection method is given in section 3. Finally, the conclusion is given in section 4.

## 2 Characteristics of Fire Used in Proposed Method

Unique visual signatures of fire are all essential for recognition. A region that corresponds to fire can be captured by spectral characteristics of the pixels and the spatial structure defined by their spectral variation within the region. The shape of a fire region usually keeps changing and exhibits a stochastic motion, which depends on surrounding environmental factors, such as the type of burning materials and airflow. To validate a real burning fire, color and dynamic features are used to distinguish other fire aliases [9].

### 2.1 Color

According to most previous fire detection methods and our experiments, we notice that color characteristics of fire are very distinct. The flames of general fire display reddish colors; the color of the flame will change with the different temperature. The color shows range from red to yellow when the fire temperature is low, and it may become white when the temperature is higher. It may be the most powerful feature for detecting fire in video sequences. For a given general fire pixel, it is noticed that the value of the green channel is greater than the value of blue channel, and the value of red channel is greater than the green channel.

This color detection metric can be used to generate the potential fire region, further, which will be analyzed with the other non-color fire features described in follow.

### 2.2 Dynamic Features of Flame

Airflow usually makes flame oscillate or move suddenly, it demonstrates the changeable shapes of fire. This can reflect the corresponding effect especially on a variable flame area in an image. The size of a fire's area in an image cannot maintain to be constant for the shape of flames is changeable anytime owing to airflow. Besides, the flame always has a growth feature. The disorder of fires can be measured with the pixel quantity of flame difference between two consecutive images. These fire dynamic features include sudden movements of flames, changeable shapes, growing rate, and oscillation (or vibrations), etc. Based on the above analysis of fire, dynamic features will be used to identify a real fire for improving the reliability of detection. We utilize both the disorder characteristic (randomness of area size) of flames and the growth of fire pixels (boundary roughness) to check if it is a real fire [10]. They are given separated by follow formulas:

$$\Delta A_i = \frac{|A_i - A_{i-1}|}{A_i}, \tag{1}$$

Where $\Delta A_i$ is the normalized area change for the $i$th frame image, $A_i$ corresponds to the area of the fire blobs representing the potential fire regions. Fire is assumed if $\Delta A_i > \lambda_A$, where $\lambda_A$ is a decision threshold.

$$B_R = P_S / P_{CH_S}, \tag{2}$$

Where $S$ is the convex hull of a set of pixels, $P_S$ is the perimeter of $S$ and $P_{CH_S}$ is the perimeter of the convex hull of $S$. Fire is assumed if $B_R > \lambda_{B_R}$, where $\lambda_{B_R}$ is a decision threshold.

## 3 The Proposed Method

The framework of proposed method is shown in Fig.1.

### 3.1 Potential Fire Region Detection

When fire occurs, the pixels of the two continuous images of video may change. After acquiring video data, we can use the frame differencing method to get the change region. Firstly, two continuous frame images are compared. If there is no evident change, then the two images are abandoned, and the system goes on detecting.

Conversely, if there is some pixels difference between them, then image should be collected, and the continuous frame image should be compared. If there is some change each time, then fire may occur, and the early fire detection may start. Described by formula as below:

$$\Delta f_i(x,y) = f_i(x,y) - f_p(x,y) = \begin{cases} 0, \Delta f_i(x,y) < T \\ 1, \Delta f_i(x,y) > T \end{cases} \tag{3}$$

Where, $\Delta f_i(x,y)$ is the difference between the two continuous frame images of the monitor video; $f_i(x,y)$ is the current image; $f_p(x,y)$ is the previous image, $T$ is the threshold. When the gray difference between the current image and the previous image is less than the threshold $T$, we believe that there is no fire for the current image may simply change slightly because of the environmental effect.

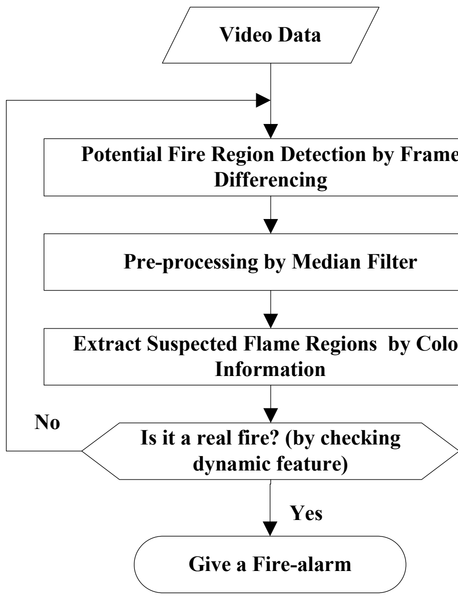


**Fig. 1.** The proposed early fire-detection algorithm

## 3.2 Median Filtering

As a typical non-linear filtering method, median filtering algorithm can remove noise at the same time retain a good image of the details of information. The basic principle of median filtering algorithm is to use the median value of all the pixel values in the filtering neighborhood of a certain point in part of an image, which is the value of the midpoint position item of all the pixel values sorted ascending or descending, to replace the value of the particular point. Medium value of the sequence of terms is defined as:

Assume a group of sequences $x_1, x_2, x_3, \cdots, x_n$, after sorted in ascending it becomes:

$$x_{i1} \le x_{i2} \le x_{i3} \le \cdots \le x_{in} (i = 1, 2, 3, \cdots, n), \tag{4}$$

Then its median value is:

$$y = Med\{x_1, x_2, x_3, \cdots, x_n\} = \begin{cases} x_{i(\frac{n+1}{2})}, n \text{ is odd number} \\ \frac{1}{2}\left(x_{i(\frac{n}{2})} + x_{i(\frac{n+1}{2})}\right), n \text{ is even number} \end{cases} \tag{5}$$

In this paper, median filter is used to smooth image. Median filtering not only can eliminate random noise in image mostly, but also can get a good distribution in the image and fuzzy image edge.

### 3.3 Suspected Flame Region Extracted by Color Information

We can easily extract the frame region by its color information. Suspected flame regions are selected from those potential fire regions according to the color information in the $RGB$ and $YCbCr$ color space. It is found that the power of $R$ (red) component will increase and the power of $Cr$ component is always greater than $Cb$ when the flame appears. So, suspected flame region can be determined when it satisfies the following formulas [11]:

$$\begin{cases} Pf_{LR} > Pb_{LR} \ \& \ Pf_{LR} > Pb_{LB}, \\ Pf_{Cr} > Pb_{Cb} \ \& \ R > 100, \end{cases} \tag{6}$$

Where $Pf_L$ and $Pb_L$ denote the $L$ band power of foreground (current frame image) and background (previous frame image) region respectively, and the subscript $R, Cr, and\ Cb$ denote the $R, Cr, and\ Cb$ color channel. To avoid the false flame detection due to the interference of background illumination or other environmental disturbance, the time varying property of flame geometry is taken into account. For the time varying geometry feature, angles of the four major corners (top, bottom, right, and left) of the flame region are calculated first. Calculating the angle by the formula:

$$\cos(Angle) = \frac{-(A^2 + B^2 - C^2)}{2AB}, \tag{7}$$

After that, the variation of the angle is estimated as follows:

$$\left| Angle_i - Angle_p \right| > Th, \tag{8}$$

Where the subscript $i$, and $p$ denote the angle of the current and previous frame image respectively. If the variation of the angle is less than the threshold $Th_{Angle}$, the flame region is marked as the false result and is eliminated. Similarly, real flame region can be examined by analyzing the variation of flame center intensity in $R$ channel. If its variance is less than a given threshold, it is removed from the flame set.

### 3.4 Fire Recognition

Bayes classifier is employed to combine the features discussed in the previous section. In order to classify the class fire from the class non-fire, and needs to estimate the mean and the variance of each class. Therefore For each frame image $f_i(x, y)$, naive set of potential fire regions is initially created based on the set of rules for color. For each potential fire region, a vector $d$ of features is obtained as:

$$d = \begin{bmatrix} \Delta A \\ B_R \end{bmatrix}, \tag{9}$$

The Bayes classifier decision function in the fire class is described by:

$$f_1(d) = \ln P_r(b=1) - \frac{\ln|C_1|}{2} - \frac{(d-m_1)^T C_1^{-1}(d-m_1)}{2}, \tag{10}$$

Where $\ln$ represents the natural logarithm operation, $b$ indicate a flag that represents one of the two possible classes, $p$ is the Gaussian density of the vector in the fire class. Correspondingly, for the non-fire class, the decision function is:

$$f_0(d) = \ln P_r(b=0) - \frac{\ln|C_0|}{2} - \frac{(d-m_0)^T C_0^{-1}(d-m_0)}{2}, \tag{11}$$

Finally, the decision surface separating the two classes is:

$$f_{10} = f_1(d) - f_0(d) = 0. \tag{12}$$

## 4 Conclusions

In this paper, an eraly fire detection method based on image and video processing technology is presented in order to avoid or eliminate the fire disasters in coalmine timely. Both color and dynamic features are used to extract a real flame that is adopted for helping to validate the fire. Further, a fire alarm is given immediately when the fire alarm raising condition is met.

## References

[1] Healey, G., Slater, D., Lin, T., Drda, B., Goedeke, A.D.: A system for real-time fire detection. In: CVPR, pp. 15–17 (1993)
[2] Phillips III, W., Shah, M., Lobo, N.V.: Flame recognition in video. In: Fifth IEEE Workshop on Applications of Computer Vision, pp. 224–229 (2000)
[3] Toreyin, B.U., Dedeoglu, Y., Gudukbay, U., Cetin, E.: Computer vision-based method for realtime fire and flame detection. Pattern Recognition Letters 27(4), 49–58 (2006)
[4] Liu, C.B., Ahuja, N.: Vision based fire detection. In: IEEE International Conference on Pattern Recognition, vol. 4, pp. 134–137 (2004)
[5] Chen, T., Wu, P., Chiou, Y.: An early fire-detection method based on image processing. In: ICIP, pp. 1707–1710 (2004)

[6] Marbach, G., Loepfe, M., Brupbacher, T.: An image processing technique for fire detection in video images. Fire Safety Journal 41(4), 285–289 (2006)

[7] Horng, W.B., Peng, J.W., Chen, C.Y.: A new image-based realtime flame detection method using color analysis. In: Proceedings of IEEE Networking, Sensing and Control (ICNSC), pp. 100–105 (2005)

[8] Celik, T., Ozkaramanli, H., Demirel, H.: Fire pixel classification using fuzzy logic and statistical color model. In: IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), vol. 1, pp. 1205–1208 (2007)

[9] Liu, C., Ahuja, N.: Vision-based fire detection. In: Proc. Int. Conf. Pattern Recognit., vol. 4, pp. 134–137 (2004)

[10] Paulo, V.K.B., Ebroul, I.: A Probabilistic Approach for Vision-Based Fire Detection in Videos. IEEE Transactions on Circuits and Systems for Video Technology 20(5), 721–731 (2010)

[11] Lai, C.L., Yang, J.C., Chen, Y.H.: A real time video processing based surveillance system for early fire and flood detection. In: Proceeding of 24th IEEE Instrumentation and Measurement Technology Conference (IMTC), Poland (2007)