Using Bayes method and Fuzzy C - Mean Algorithm for Fire Detection in Video

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***Abstract* - This paper proposes a new approach that combines Bayes method and fuzzy C - Means Algorithm in order to detect the movement of objects, and determine the fire color pixels in RGB space**

Keywords - Fire Detection ;Bayes method; C-mean algorithm; Fuzzy logic; Fire flicking.

I. INTRODUCTION

Nowadays, there are more and more fire detection systems are being used widely in supermarket, store, airport and family, etc. Almost of these fire detection systems are based on sensor, including temperature sensors, smoke sensor, etc. Although fire detection system based on sensor has so much advantage, but they still contain many disadvantage, because of their essentials. Another approach to build a fire detection system that based on image processing technologies has been studied for many years, and harvested many achievement.

Visual fire detection can be useful in conditions where conventional fire detectors cannot be used. Existing methods of visual fire detection rely almost exclusively upon spectra analysis using rare and usually costly spectroscopy equipment. This limits the fire detection to those individuals who can pay high prices for expensive sensors that are necessary for these methods. Moreover, these methods, still procedure false alarm in the case of objects whose colors are almost the same as fire, especially sun, light, etc

In this paper, we propose a method that uses statistical theory, fuzzy c-means algorithm and a fire flicking analyzing method. A background modeling method using Bayes statistical theory is explained in Section II.A. Section II.B describes a way finding the clustering of fire domain in RGB color space, that using C-means algorithm. To improve the efficient of system, we propose an algorithm which was used to analyzing the fire flicking.

II. BAYES METHOD AND C-MEAN ALGORITHM

A. Statical and Bayes method

In order to detect possible changes, which may be caused from fire, we need to use an effective background-modeling system. This algorithm should be simple and robust to achieve a real-time detection of fire.

Background modeling used in our system uses a method looks similar to an algorithm was described in [18], so that the system should be applied in the environments that the scene observed is almost stationary and the camera 's position is fixed. The background is modeled with unimodal Gaussian, with mean and covariance matrix extracted from incoming image where incoming image where incoming image is composed of Red, Green and Blue components

The distributions of color channels of the each pixels are assumed to be independent, and modeled using a unimodal Gaussian whose parameters are settled in the training phase of the system. So for each pixel, an overall distribution model is estimated as follows:

$$p(I(x, y) = p_R(I_R(x, y)) * p_G(I_G(x, y)) * p_B(I_B(x, y). \quad (1)$$

where p_R, p_G, p_B are distribution model for Red, Green and Blue color channel respectively, I(x, y) is pixel value at location (x, y) with p(I(x, y)) is an approximately for probability density of I(x, y). We use unimodal Gaussian, so each distribution is assumed to be independent of other distributions.

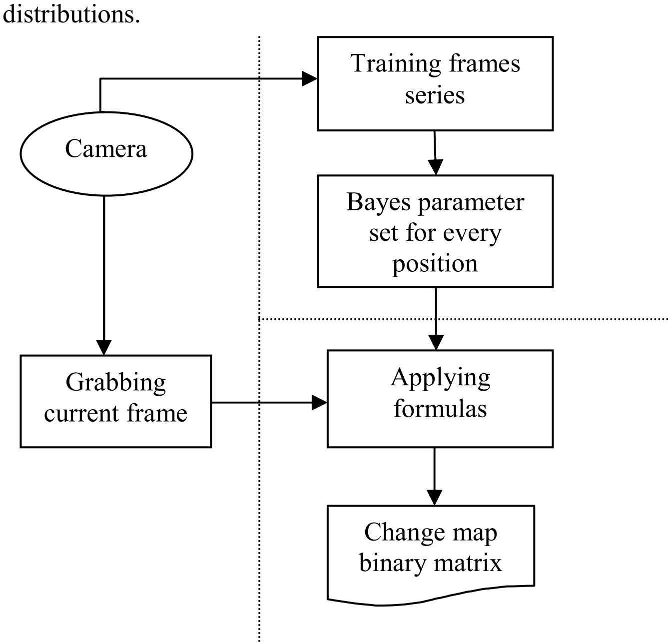

Figure 1. Motion detection using Bayes statistical

Apply Bayes formulas for series of frames grabbed from camera in training phase, we can get mean and covariance values for each color channel of every position. In our system, we use a training period of 10s. Hence the overall scene is observed for 20s, since the frame rate is 30fps, a statistics over 300 frames are used to extract initial values for $\mu_i(x, y)$ and $\sigma_i(x, y)$.

Using mean and covariance extracted, we can decide that a position (x, y) contained movement object or not by using the following formula:

$$B_i(x,y) = \begin{cases} 1 & |\mu_i(x,y) - I_i(x,y)| \geq \alpha_i \sigma_i(x,y) \\ 0 & otherwise \end{cases} \quad (2)$$

where α_i is a global constant, which effect the final change detection map. We should increase α_i if setting up system in the much noises environment and camera quality is not good, in contrast, in the good quality environment, we should increase α_i. Finally, a binary matrix CM that marks changed positions on camera region will be created by using follow formula:

$$CM(x,y) = \begin{cases} 1 & (\sum_{i=\{R,G,B\}} B_i(x,y)) \geq 2 \\ 0 & otherwise \end{cases} \quad (3)$$

As detailed in formula (3), a fixed position (x, y) will be marked as movement position if there were at least 2 color channels that change values at that position.

B. Data clustering and C-Mean algorithm

In this step, we used method which was detailed in [17], this algorithm tries to create a data look up table, called dominant flame color look up table (DFCLT). This table will be used to determine a pixel in RGB color space belong to fire color region or not. The below diagram demonstrates the steps required to apply FCM algorithm in our system.

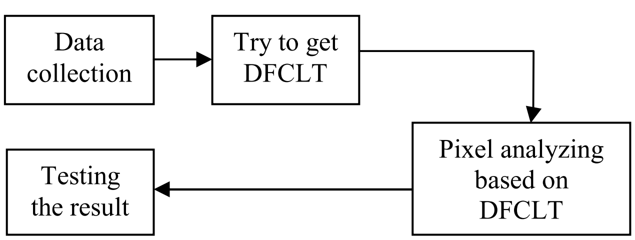

Figure 2. Pixel analyzing

To acquire the DFCLT, the video sequences of burning process are taken in many environment under safety control. For every image, we created a pair of image, include original image and a binary matrix that marks fire positions. From these pairs, we can collect a dataset of RGB values of fire pixels. After data collection phase, we collected a dataset with 1.051.521 samples.

In the next phase, the fuzzy c-means (FCM) algorithm is used to group pixels into clusters according to RGB color feature. The aim of FCM algorithm is to minimize the error function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{c} u_{ij}^m \|x_i - c_i\|^2, 1 \leq m < \infty \quad (4)$$

where x_i, i = 1÷N, is the list of samples in our dataset; c_j, j = 1÷c is the center of clusters j in RGB space. U is a correlation matrix, with u_{ij} is correlation coefficient between i*th* sample and j*th* cluster.

Our aim when applying FCM algorithm is to retrieve the center of 5 clusters belong to fire color in RGB color space. A detailed description of the clustering algorithm is given as follow:

Input: Dataset with RGB color features.

Output: 5 clusters with pixels.

c represents the center of clusters, m the exponential weight and u_{ij} is the membership values.

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|} \right)^{\frac{2}{m-1}}} \quad (5)$$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m x_i}{\sum_{i=1}^{N} u_{ij}^m} \quad (6)$$

Step 1: Initialize parameters m and c; then assign values to u_{ij}'s using either a random function or an approximation method.

Step 2: For each cluster c_j, update center using (6) and u_{ij} using (5).

Step 3: Check the finish condition:

$$\max\{|u_{ij}(t) - u_{ik}(t-1)|, i = 1 \div 5; j = 1 \div n\} \leq \varepsilon$$

If above condition is satisfy, stop loop sequence then finish algorithm, current value of c is center of cluster that we need. Otherwise, when finish condition is not satisfy, move backward to Step 2, and the loop sequence continues.

When applying FCM algorithm, with m = 2; ε = 0.002, the algorithm finished after 8 sequence loops, we retrieve DFCLT that demonstrated in table 1.

TABLE I. COLOR-LOOKUP TABLE

Class	*R*	*G*	*B*
Cluster 1	232	147	69
Cluster 2	248	200	95
Cluster 3	249	236	112
Cluster 4	249	247	198

Class	*R*	*G*	*B*
Cluster 5	253	253	250

DFCLT will be used to determine that a sample with (R, G, B) value belong to fire domain or not by calculate the distance between the candidate pixel and nearest cluster (we use Euclid distance function in RGB space). If this distance higher than a predetermined threshold, this candidate will be fire pixel, otherwise, this will be background.

We tested the FCM algorithm with images and video sequences that were captured in many others environment, including sunny, day, night, etc. and calculated error ratio. The result is detailed in the table below:

TABLE II. FCM TESTING RESULT

Number of samples: **300.000**		
Number of fire samples : **165.386**		
Number of background samples : **134.614**		
	Count	Ratio (%)
True classification	**171.087**	**57,03**
False classification	**128.913**	**42,97**
False classification from fire pixel to background pixel	**21.789**	**16,90**
False classification from background pixel to fire pixel	**107.124**	**83,10**

With false classification ratio at 42,97%, this algorithm seems to be not good. But when applied with other method, this is an important feature for the fire detection problem.

III. FIRE FLICKING ANALYSIS

The combining background modeling and color detection did not bring about good result, especially when testing system in noisy and much movements – environments. So we propose another method, focus in analyzing the flicking of fire.

Many research pointed that the flicking frequently of fire is about 10Hz. We analyze this frequently by drawing a diagram, as shown in figure 3:

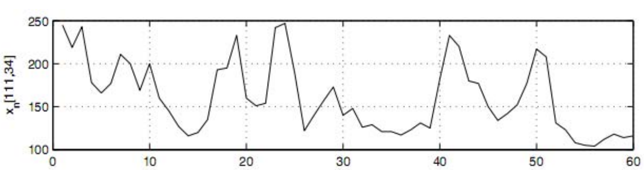

Figure 3. Frequency of fire flicking

Where vertical axis describes Red channel of pixel and horizontal axis describes real time. The above diagram shows the value of Red channel of a pixel at a fixed position through continuous frames. We use Red channel because it contains fully description about fire color.

Fire flicking analyzing is done by counting the times that Red diagram (Red = T_R) diagram, where T_R is a threshold that declared before, we use $T_R = 200$. If in a fixed count of frames, the cutting times more than a number declared before, that position can be set to be fire pixel.

IV. ALGORITHM

Finally, we propose an algorithm that combines all 3 algorithms that mentioned above. This algorithm is very simple, it looks like applying 3 filters to every pixel in every sequences grabbed from camera at the same time. Including motion detection filter, fire flicking filter and fire color filter.

Our algorithm include 2 phase:

Phase 1: (Training phase)

Capture continuous frames from camera for 30s, these frames will be used to create a set of Bayes parameter for every position (detailed in Section II.A). These frames will be simultaneously used to get and store a fixed number of Red value for fire flicking filter, as detailed in Section III.

Phase 2: (Fire detection phase)

With parameter retrieved from Phase 1, for every frame grabbed from camera, our system will scan every pixel in frame, apply motion detection filter to get Change Map (CM) binary matrix. Scan positions in CM matrix where value is True, then apply fire flicking filter to this position.

Positions which passed both motion and flicking filter will be check RGB color values in fire color analyzing filter, as detailed in Section II.B. Finally, the output of filters are fire pixel, other pixel will be treated as background pixel.

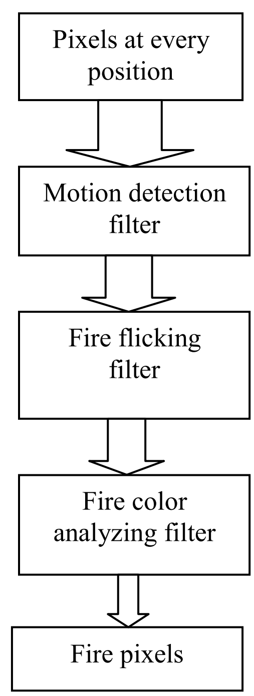

Figure 4. Combine 3 filters at the same time

After get fire pixels positions in frames, calculate the ratio between total number of fire pixel and total pixel in whole frame size. This ratio will be used to determine the “fire level” of current frame. The more ratio, more dangerous level must be raised. Our system used following fire level:

$0\% \leq$ Ratio $\leq 0.5\%$: Blue level

$0.5\% <$ Ratio $\leq 1.0\%$: Yellow level

$1.0\% <$ Ratio $\leq 2.0\%$: Orange level

Ratio $> 2.0\%$: Red level.

In actually, the real fire frame will have Ratio at least 1.5% and more..

V. Result And Discussion

We tested our system with 20 video sequences which was captured in different environment, include fire scenes in sunny, day, night, and sequences contain movement objects with as high frequency as possible.

After analyzed result, we recorgnized there was 3/20 video sequences that transmitted false alarm when treated with movement object as fire objects. In another hand, there is only one fire sequence which system could not detect.

False alarm was rise when natural movement object contained as fast flicking as fire pixel. And our system did not raised alarm with sequence that captured in hight light environment, when fire movement couldn’t be detected. But when tested in a not-too-bad environment, the system worked well.

VI. Conclusion

Fire detection is a difficult problem. There have been many methods proposed to resolve this problem but up to now, there is not perfect method or algorithm which solve this problem fully.

In this paper, we propose a method that focus in analyzing visual feature of fire image, including the movement, flicking and color feature in RGB color space. Our method is applied in conditions where camera position is fixed and environment is rather clear, such as in a room, building. It easily raise false alarm or cannot detect fire when using in bad environment or in a large area, where camera cannot capture image large enough.

Here we would like to mention the following areas of investigation which may merit further study:

1. Try to develop method in other color space, such as HSI or YCrCb.
2. Combine the characteristics of color, shaped, texture, and spatial relationships to improve the performance.
3. Use image pre-processing to improve the image quality before using our method.
4. Try to apply the proposed method in condition where camera is not fixed, by using Shift – method, such as Mean-shift, CAM Shift, etc.

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