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Fire Detection using Computer Vision Models in Surveillance Videos

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Abstract: CC cams are everywhere and in this work, we explore these sensors ability and the corresponding algorithms to detect fire. The two drawbacks that rises questions on the performance of fire detection algorithms are: (1) Ambient lighting that masks the fire for colour feature based detection and (2) Sizeable object movement near the fire for dynamic change based algorithms. This paper address these problems with cc camera footages of fire in indoor and outdoor environments under the two problematic conditions. We test models on colour, frame subtraction, back ground modelling with Gaussian Mixture Models, Independent component analysis, Geometric – Independent component analysis (GICA). A 4-parameter statistical model checks the quality of the proposed algorithm. Results show the potentiality of the proposed algorithm is solving the above two problems for fire detection.

Keywords: *Fire detection, Fire segmentation, Indoor and outdoor fires, Geometric Independent component analysis.*

1. INTRODUCTION

Smoke sensors and corresponding water pumps are a part of automated fire protection mechanism from past few decades. But they are still gaps in the indoor environment fire sensors which tend to sound alarm only when the fire or smoke touches the sensor. By this time the fire becomes uncontrollable and water pumps efforts to contain fire becomes impossible. The other gap is in containing outdoor fires that occur and cause damage in the fields, outdoor storage spaces and oil storage places. It is not possible to install fire sensors in the outdoor environment whereas we find CC cams that monitor these outdoor environments all the time.

In the last decade, computer vision has touched every industrial automation system and fire detection is no exception. Using the existing infrastructure of closed circuit cameras (CC).

In previous works on Fire Detection by Using Digital Image Processing [1] has been used to study of the flame detection in video through motion and edge detection techniques. Identifying grey scale Images of the flame. It's optimizing technique to detection of the flame, which generated because of smoke and of spreading fire pixels. These systems can be used to reduce false detection fire. Novel method is used to simulate the given method with the existing methods and give optimized way to detect the fire in terms of less flame detection. Author has described his work into two steps. (1) This step involves edge detection. (2) second step involves motion detection. The input which he had taken from the video as a frame, he had applied canny method for detecting the edges. In the 2nd step he had taken the two-successive frame from the surveillance video later on he compared their equivalent RGB values. Based on their relation we can evaluate the moving-fire region. Forest Fire Detection [2] is also used to obtain a solution. In this Mamdani proposed an Algorithm in which overlapping problems greatly reduced by combining the several ones into one. In this way, the conclusions obtained by our FSLs avoid the bad results obtained by an inadequate overlap expressions. they tested their proposal on a real time using wireless sensors network.

Video Fire Detection [3] video surveillance cameras and computer vision methods are widely used in many security applications. it is also possible to use security cameras and infrared surveillance cameras for fire detection. Based on Intelligent video processing technique for detection and analysis of uncontrolled fire behaviour. VFD can help to reduce the detection time compared to the currently available sensors in both indoor and outdoor. They can also provide the direction of propagation of the fire. Eni's cetin has worked on fire detection through video surveillance cameras. Along with the computer vision methods, he has proposed IR based model. Video fire detection compared with existing fire detection methods like smoke detectors, heat sensors it provides optimized results. Sensors would not be reliable in large volumes like forests, large building, storage volumes etc.by using VFD we can overcome those problems. Author described his work by developing a colour detection model, and the combination of them like RGB and HSI\HSV. He considered smoke, flame as the moving objects and used them for further analysis like background subtraction, temporal difference, and optical flow analysis. Later then he moved on to frequency analysis like wavelet, Fourier analysis to separate flames from the moving objects. Time-variant behaviour of the smoke can be explained by wavelet domain energy analysis. Fast fire flame detection [4] Real time detection of fire flame in video scenes form a surveillance camera offers early warning to ensure prompt reaction to devastating fire hazards. there are several existing methods for detecting fire through surveillance cameras, but they give high-false alarm rates. By using logistic regression and temporal smoothing we can greatly reduce the false alarm rates. temporal smoothing is employed to reduce false alarm rate at a slight decrease in sensitivity. Experiments conducted on various bench marking data bases demonstrate that the purposed scheme successfully distinguishes fire flame from background as well as moving fire like objects in the real world indoor-outdoor video surveillance settings. and compared average detections for each detection method. fastest was state-of-the-art-video-based fire flame detection technique for comparison. In this Video fire detection and its application [5] Video fire detection makes a significant contribution to the effectiveness of fire detection systems, particularly as regards fire in large spaces such as Atria, Tunnels, Hangers, Warehouses and E&M Plant rooms, as traditional fire detection systems have been shown to be ineffective in large spaces. For the development of video fire detection systems, spatial, spectral and temporal indicators are important in the identification of a fire source. In the development of video fire detection systems, flame image segmentation, recognition, tracking and predication are important areas of investigation. The multi – threshold algorithm of Otsu's method and the Rayleigh distribution analysis method (modified segmentation algorithm) can be used in the segmentation of flame images. The modified segmentation algorithm, however, can be strengthen to extract the pool fire images making use of the optimum threshold values. Following such segmentation, the pool fire images centroid analysis technique can be used to recognize pool fire images by means of the Nearest Neighbour (NN) algorithm. The objective of this paper is to examine the modified segmentation and the NN algorithms. Adaptive flame detection [6] is a study of detection of flame colour probability, motion probability based on Gaussian distribution model in YC_bC_r colour space.by then combining the both colour probability to obtain flame components, by which a vector is features of flame region then the successive flame region is applied to Wald Wolfowitz randomness test to obtain prior probability. Contagiously flame region motion change can be observed and corresponding probability calculated. Later on convolution applied to prior probability to the post probability to improve system reliability and this method was implemented successfully. Flame detection in video using hidden Markov models [7] differentiate flame and flame coloured objects. Colour variations in the flame are also evaluated by the same markov model. By combining all these clues, we can reach final decision of fire detection. In computer vison based method for real time fire and flame detection [8] Processing the video data generated by ordinary monitoring/surveillance camera, in addition to object motion, fire motion, flame flickers are detected by analysing the video in wavelet domain. By irregularity in the boundaries of fire region, clues generated. By combining all the above clues author reach to a final decision. enables us to detect the extract position of an event at an early stage. By testing and verification process the experimental results was studied.

2. FIRE DETECTION ALGORITHM

The proposed fire detection algorithms are used to detect fire by CC cameras for indoor and outdoor fire. Figure 1 shows few fires in indoor and outdoor.

(*a*) Indoor Morning Fire (*b*) Indoor Night Fire

(*c*) Outdoor Morning Fire (*d*) Outdoor Night Fire

Figure 1: Some Examples of the fire images

2.1. Rule Based on Color Models

Colour is one of the important basic feature of an Image. Image is nothing but a group of different colours. Any pixel of an image is defined using three colours R, G, B (Red, Green, blue). Based on those characteristics we can evaluate the Image. Intensity characteristics of the fire can be studied. If the colour of fire flame dependent on the type of fuel involved in combustion. Different types of flames depend on oxygen supply. In the initial stage fire colour is blue. Flickering flames have red colour. If the temp is more than 1000 fire changes to orange colour and then transforms to the white colour. Based on these colour characteristics we develop a rule based generic model consists of three rules 1) Compare every pixel value R, G, B Respectively in Ascending Order 2) By setting a threshold for Red pixels. 3) Evaluate image by mathematical equations.

$$R > G > B \tag{1}$$

$$R > R_t \; (R_t = 150) \tag{2}$$

$$S_2 > S$$

where

$$S = (255 - R) \times (S^t / R_t) \tag{3}$$

$$S_2 = 1 - 3 \times \left(\frac{B}{R + G + B} \right) \tag{4}$$

Figure 2 Shows the experimental results of the RGB based fire detection algorithm [9]. ere 2(*a*) represents some fire images by taken CC cams, 2(*b*) images are the rule 1 based fire detection results and 2(*c*) is the rule 2 based fire detection.

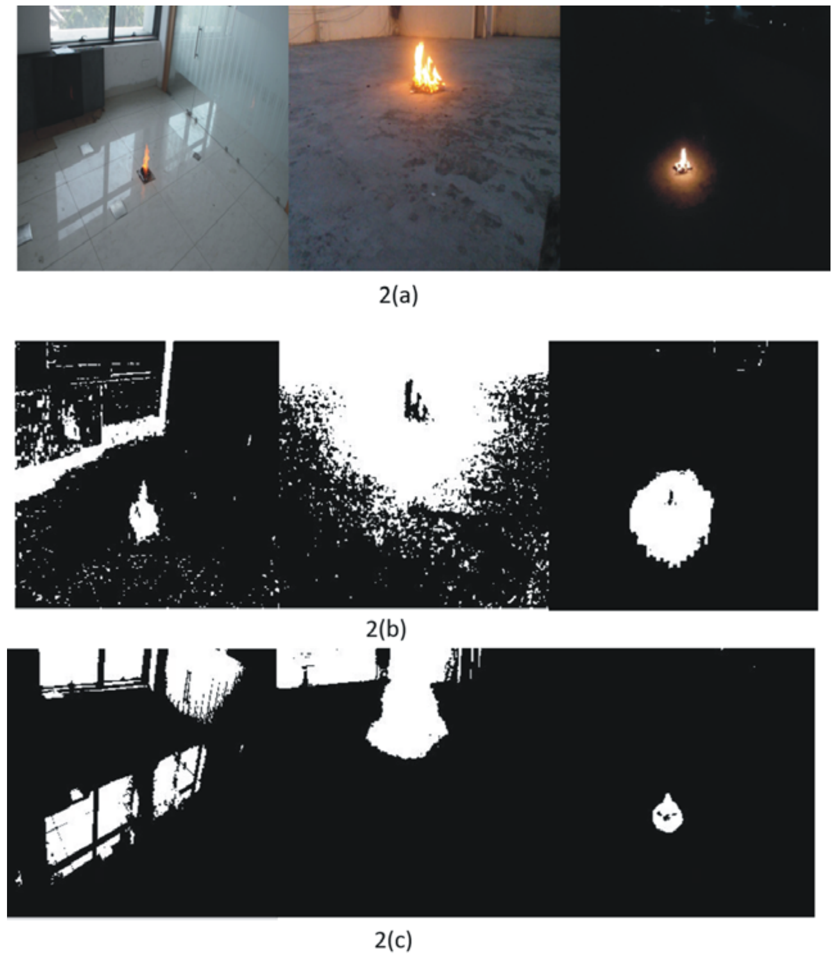


Figure 2: The RGB images give in two cases of fire regions

However, Using RGB colour models results in false fire detection. So, we had moved to Another colour model HSI (Hue, Saturation, Intensity). Hue- colour shade which varies from 0-360. Saturation- how much colour is polluted with colour Intensity- Intensity of fire in a Binary image.

$$h_1 \leq H \leq h_2$$

or

$$h_s \leq H \leq h_t$$

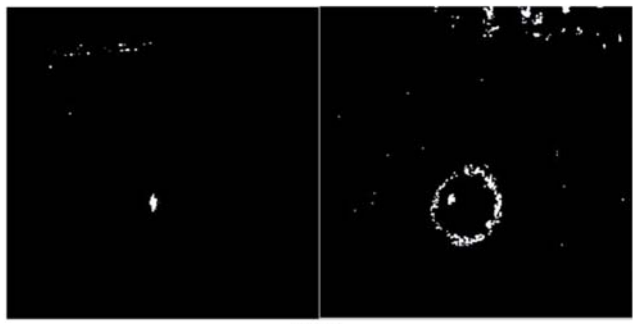
$$S_1 \leq S \leq S_2 \tag{6}$$

$$I_1 \leq I \leq I_2 \tag{7}$$

From this colour model depending upon these parameters we can evaluate the fire candidates in an Image. We develop rule based generic model.

Pixels which obey all these conditions will give respective fire regions. However, HSI colour models [9] are also not satisfactory it is also detecting other colour objects in the Image. Based on this fact we combined with the results of RGB, HSI by applying AND operation for the respective Image. This can reduce false detection rate exponentially.

3(a)



3(b)

Figure 3: The HSI images of the Fire regions

The above figure 3 shows the HIS binary images obtain fire regions. Here 3(*a*) is the fire video frame and (*b*) is the HSI based fire detection.

The above figures 2 & 3 clearly shows the second case of the both RGB and HSI rules find false fire regions.

2.2. Gaussian Mixture Model (GMM)

Fire in Video Image is dynamic in nature which is constantly moving. Based on this assumption we can separate fire region which is in foreground from background using GMM. This model of each pixel with four Gaussian Distributions.

$$\mathrm{P}(\mathrm{X}_n) = \sum_{j=1}^{k} w_j \eta\left(\mathrm{X}_n ; \theta_j\right) \tag{8}$$

$$\begin{aligned} \eta(\mathrm{X} ; \theta_k) &= \eta(x ; \mu_k , \Sigma_k) \\ &= \frac{1}{\sqrt{2\Pi |\Sigma_k|}} e^{-\frac{1}{2}(x-\mu_k)^{\mathrm{T}}} \sum_{k}^{-1} \left(x-\mu_k\right) \end{aligned} \tag{9}$$

$$\mathrm{K}_{\text{foreground}} = \mathrm{K}_{\text{current}} - \mathrm{K}_{\text{background}} \tag{10}$$

Fire region gradually moves from frame to frame, when we consider two successive frames there wouldn't be much change. But, when we consider certain interval of frames we can observe variations more precisely. By doing some experimentation we choose an interval of 7 frames, by then we extract the foreground using equation.

After that we convert foreground image into grayscale image. Then we use Otsu's Algorithm to set some threshold level for obtaining black and white Image. Pixel values below threshold level marks as black, above threshold value marks as white.

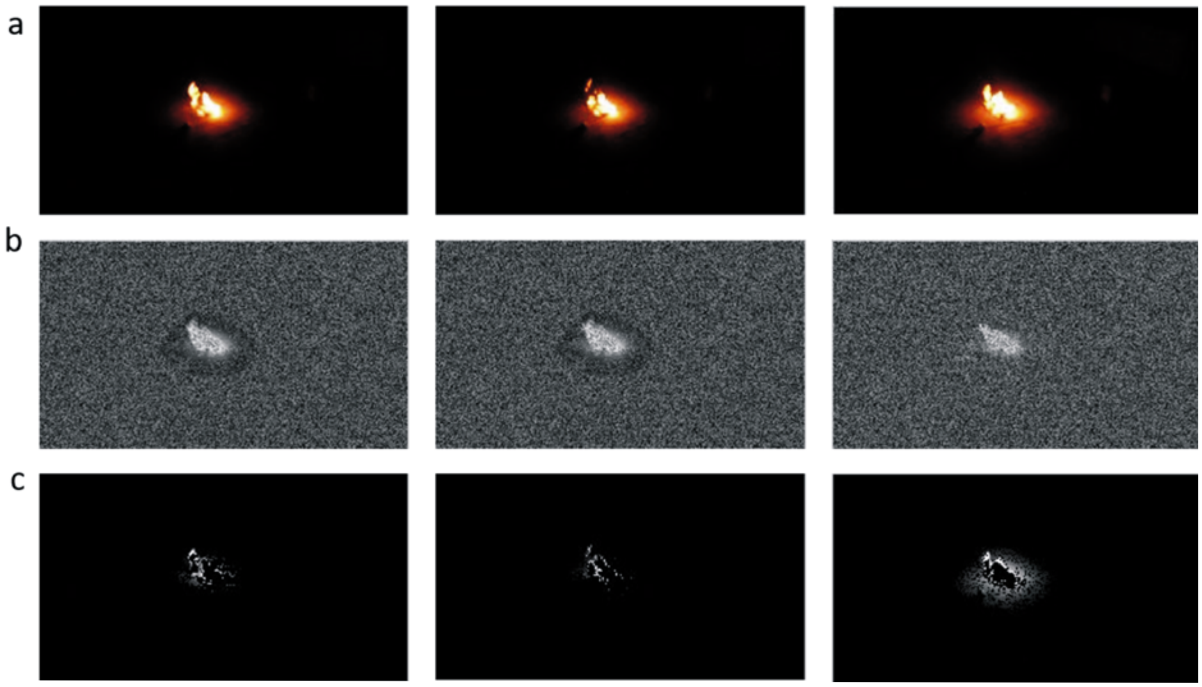


Figure 4: Fire Detection obtain by GMM Model

The fire detection by using Gaussian Mixture Model gives better results when compared to the RGB & HSI rule based models. Figure 4 shows the GMM based fire region detection in a video frame. Our proposed model GICA gives the better fire detection and the detection speed is increase when compared to the other models.

2.3. Geometrical Independent Component Analysis (GICA) Model

So far, we consider image. Then we moved to video fire, Fire is in dynamic nature which constantly change from frame to frame. In order to approach this level that we moved to most sophisticated technique A novel algorithm for Independent component analysis [8], in which original independent signals were differentiated from the original signals. it can be used to solve the problems like cocktail party problems.

$$\begin{pmatrix} X_1^{(1)}(t) \\ X_2^{(1)}(t) \end{pmatrix} = \begin{pmatrix} 1 & \alpha \\ \beta & 1 \end{pmatrix} \begin{pmatrix} X_1^{(0)}(t) \\ X_2^{(0)}(t) \end{pmatrix} \tag{11}$$

Output signal is linear transformations of input signal. The output signals can be obtained by the inverse transformation of mixed signals. Successive frames from the fire video are fused in such a way that the ratio should be maintained as 6:4 and 5:5. those frames which we considered are converted to grey scale images. Those images were mapped into the scatter space which results in scattered space which results in scattered plot of two images. The series of geometrical transformations were applied for getting quality of information. Later on remapping has been done for differentiating the original signals from the mixed signals.

Geometrical Independent Component Analysis [10] is an extension of ICA we can extract original signals from a mixture by applying linear transformations to them. We fuse two frames from video Images in different proportions let's say 4:6 and 6:4 and apply scatter plot for them. GICA accomplished by transformation of scattering diagrams. By applying different transformations like Shearing, Scattering, Translation, Rotating for quality of Information. GICA accomplished by Geometrical transformation of scattering diagrams. We evaluated the performance of the Algorithm in real and we got effective results.

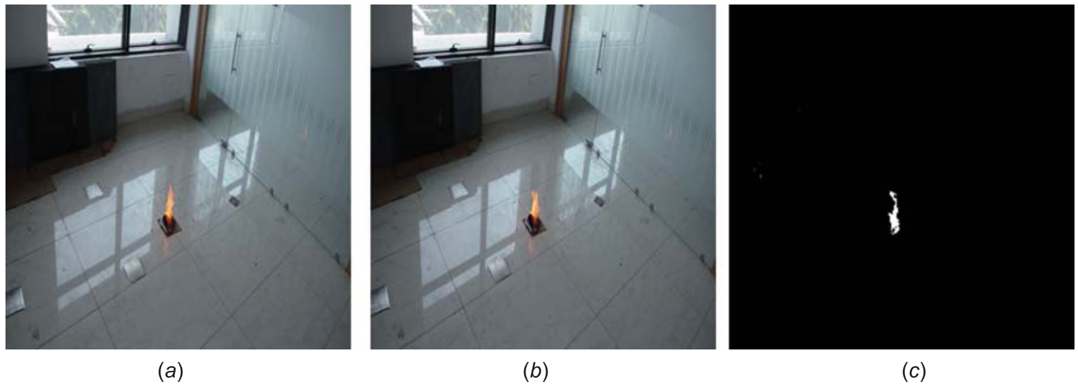


Figure 5: Two image frames form a fire video, and GICA based motion detection

Figure 5 (*a*) and (*b*) shows the two sequent video frames, those scatter gray level diagram cooperatively plotted in figure 6. The CC cams are fixed in a stationary view angle, the scatter diagram signals are concentrated the around 45°. By observation the scatter diagram rotates around 45°, then T_1 and T_2 are the thresholds to eliminate background form moving objects as shown in figure 6(*b*) & 6(*c*). The figure 5(*c*) shows the scatter points mapping to the moving object.

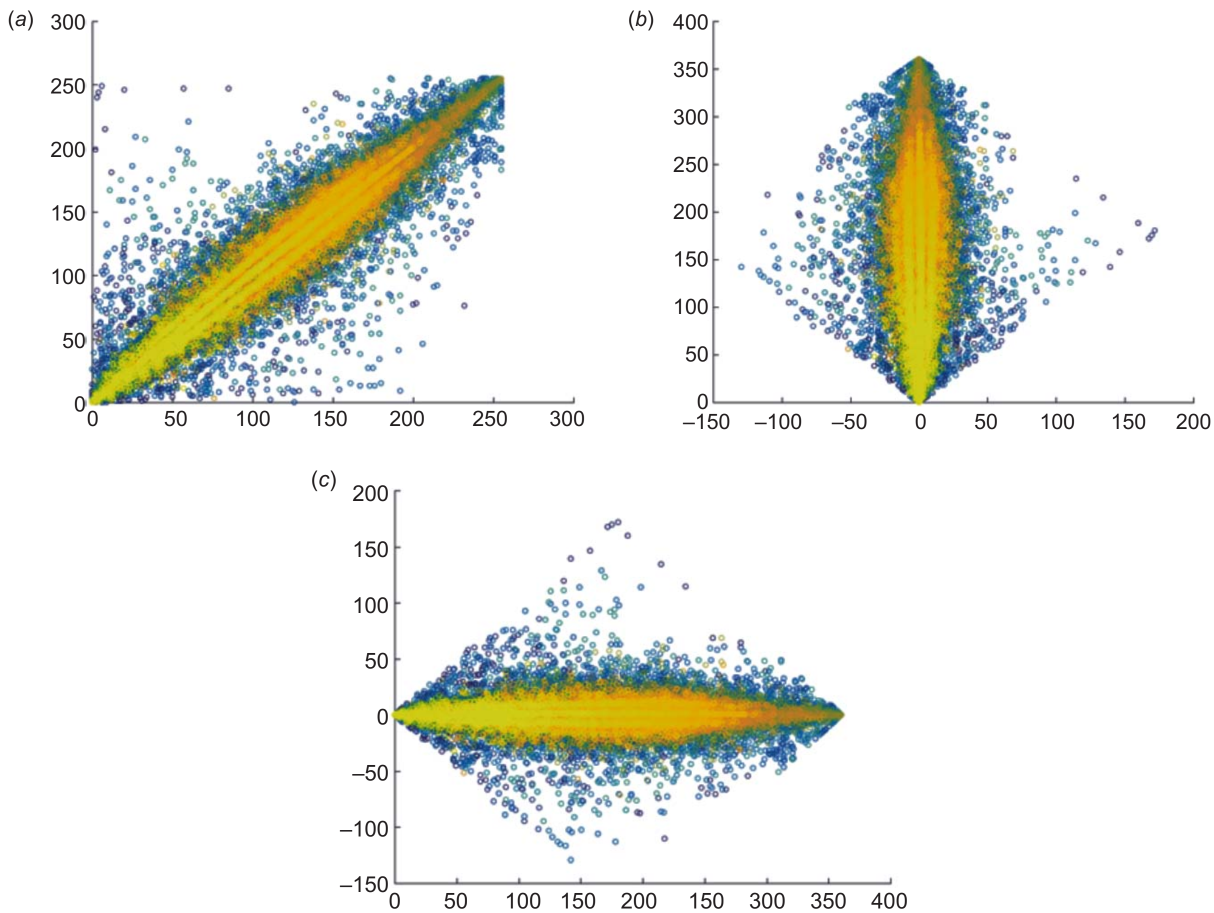


Figure 6: Fire detection transformation in GICA

3. TESTS AND ANALYSIS

The working of proposed algorithms for fire detection was verified by Indoor & Outdoor video clips be taken in CC cams. Figure 6 shows the 5 fire image frames, No. 101, No. 125, No.132, No.151 and No.191, take out from Indoor fire video at night. In the fire is visible to observe in all taken frames. The target tracking and recognition method successfully track the fire. The minimum time taken for fire detection is ≤ 4.1 *s*.

Figure 7: Indoor fire detection results at different video frames

The proposed algorithme test at different Indoor and Outdoor video frames with resolution of 256× 256. The following 8 test video frames are taken to 4 are Indoor fire frames and another 4 are Outdoor fire frames. The proposed fire detection algorithm compare with three algorithmes proposed by Zhu [9] and Rong [10]. Figure 8 shows the results of the 8 different fire video frames. And successfully the fire detection regions are detected by red boxes.

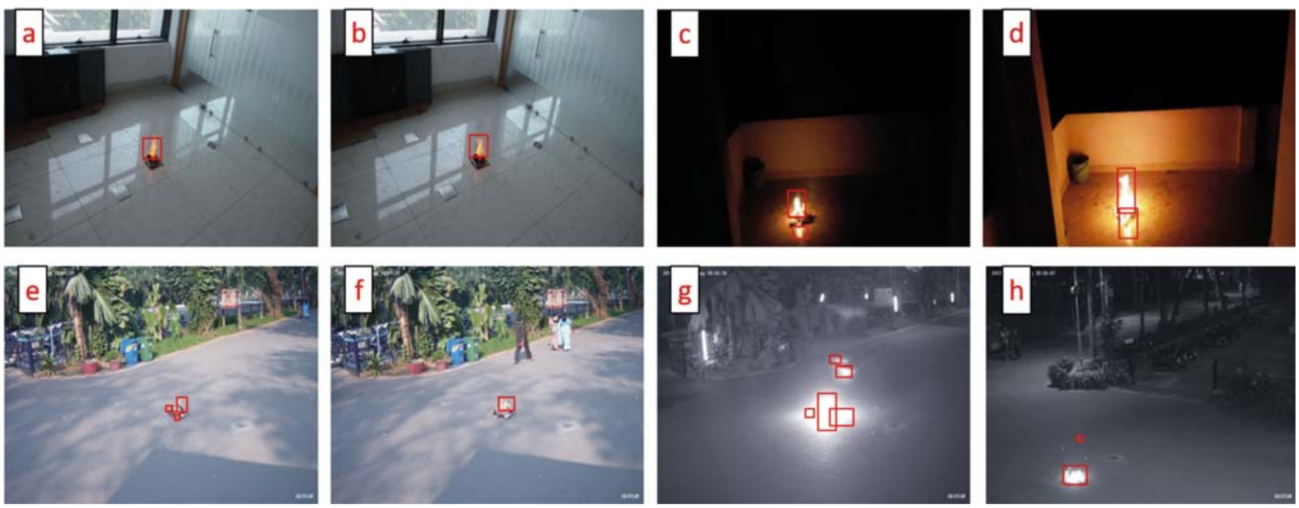


Figure 8: The 8 fire scenes for testing

In overview, compared with RGB, HSI and GMM algorithm, the proposed fire detection algorithm is showing better performance for this application.

4. CONCLUSION

In this work, Fire is being detected using CC cameras under various environments. We use color based rules, Gaussian mixture model based background elimination and Geometric Independent component analysis for extracting fire from a video sequence captured using CC cameras. Fire segmentation using color based rules is a better model with RGB videos where the red color of the fire dominates the background. However, color rules are not independent of the lighting conditions in the video. The best model for extraction of fire is GMM. The drawback is it slow computation. Hence we propose to use GICA based model to extract fire segments in video sequences. The results show GICA's superiority in fire detection and is also faster than GMM.

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