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Survey on Image Processing Based Fire Detection Techniques

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ABSTRACT

Fire accidents are very frequently occurring disasters, which causes great loss. This gives rise to the urgent need to detect fire as fast as possible. The traditional fire detection system detects the fire using temperature sensors by sense the heat generated by the fire. This paper is a study of various Image processing techniques implemented to detect the fire. It is not possible to judge whether the region detected as fire is actually a fire, because the color of fire can range from red yellow to almost white. So it is difficult to detect the fire region only by a single feature color. This paper represents the study of the recent fire detection techniques and multiple experts used in each technique.

Index Terms: fire detection, image processing, algorithms, video, video processing.

1. INTRODUCTION

Image processing is a technique which performs operations on an image to get an enhanced form or to know some characteristics of the image. It is a type of signal dispensation in which input is an image. It is one of the advanced technologies using today, for different sort of applications. Apart from human beings, who cannot visualize electromagnetic field (EM) spectrum, imaging devices can cover the entire EM spectrum like gamma and radio waves.

They can operate on images generated by sources that humans are not accustomed to associating images. Thus digital image processing encompasses a wide and varied field of applications. The conventional technique [1] for fire detection shows that fire can be detected precisely only by the time variation of its geometry, color, or other distribution information. Flame candidate region can be extracted simply by its color information. First, a preprocessing process is used to extract the difference image regions of two successive images. After that, suspected flame regions are selected from those 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 as the flame appears.

S. Saponara, L. Fanucci [2] proposed a fire detection technique which uses common video surveillance cameras, operating in visible spectrum, which are available at low cost or are already installed in the indoor scenario. The algorithm has been verified with large set of test videos in indoor scenarios and implemented in a DSP based platform and a board size of 10 cm. In [3] YCbCr color space based detection instead of the RGB space was introduced. In [4] a Multi Expert System (MES) was employed to make the decision by combining the opinions of the different individual classifiers.

For blob evaluation three techniques are used: the first is based on color, the second analyzes the shape of the blobs detected in previous frame, and the movements of the blobs are evaluated in two consecutive frames in the third. This technique has been demonstrated on many videos. It detects the fire if those three characteristics matches the content in video otherwise it rejects.

An algorithm for real time video based flame detection was proposed in [6]. By modeling both the behavior of the fire using various Spatio-temporal features and the temporal evolution of the pixels intensities in a candidate image block through dynamic texture analysis, they can have high detection rates, while reducing the false alarms caused by fire-colored moving objects. Similarly the work presented in [7] expressed the idea of implementing fuzzy logic on the information collected by sensors. The collected information was passed on to the cluster head using event detection mechanism. Thus multiple sensors are used for detecting probability of fire as well as direction of fire. Punam Patel, Shamik Tiwari proposed an algorithm in [8], they used a combined approach of color detection, motion detection and area dispersion to detect fire in video data. First, the algorithm locates desired color regions in the video frames, and then determines the region in the video where there is any movement, and in the last step they calculate the pixel area of the frame. The combination of color, motion, and area clues is used to detect fire in the video. Wen-Bing Horng and Jian-Wen Peng in [9] proposed a fast and practical real-time image-based fire and flame detection method based on color analysis. They first build a fire flame color feature model based on the HIS color space by analyzing 70 training flame images. Then, based on the above fire flame color features model, regions with fire-like colors are roughly separated from each frame of the test videos. N. Brovko, R. Bogush proposed an algorithm in [10] that uses motion and contrast as the two key features for smoke detection. Smoke detection is achieved practically in real-time. The processing per frame is about 15 ms for frames with sizes of 320 by 240 pixels. The algorithm considers both dynamic and static features of a smoke. This method has the advantage that during its operation. However, since the motion information is only taken into account by considering the temporal derivatives of pixels, without an estimation of the motion direction, the system, when working in non sterile areas, may generate false positives due, for instance, to flashing red lights.

This paper is organized as follows: Section II describes the comparative study of various fire detection techniques; various fire detection techniques are in the Subsections II-A to II-G. In Section II-H the proposed approach over recorded and live video are shown, and the conclusion is given the Section III.

2. COMPARITIVE STUDY

A. Advanced Real Time Fire Detection in Video Surveillance System

In [1] Chin-Lun Lai, Jie-Ci Yang presented a simple and effective algorithm for detecting the fire calamity event via real time video automatically in the monitoring area contents analysis. By observing and utilizing features of fire event, a fast and exact detection process is developed for early fire warning purpose thus to reduce the loss caused by fire accidents. The experimental results show that this algorithm not only achieves real-time requirement and has better performance (more robust and correct) than the compared surveillance systems, but also attains the goal of alleviating the existing system cost efficiently. The main objective of this work is to develop a fully automatic warning system for potential danger in the monitoring area via video content analysis technology, while is dedicated in fire event detection here. According to [1], fire can be detected precisely only by the time variation of its geometry, color, or other distribution information. Flame candidate region can be extracted simply by its color information. First, a preprocessing process is used to extract the difference image regions of two successive images. After that, suspected flame regions are selected from these 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** as the flame appears.

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B. *Real-time Imaging Acquisition and Processing System to Improve Fire Protection in Indoor Scenarios*

S. Saponara, L. Fanucci proposed an imaging acquisition and processing system for early smoke detection in indoor scenarios such as home/office, warehouse, industrial building, or on-board vehicles was presented in [2]. The objective if this paper was to integrate sensors to detect the heat with the results of a video-based smoke detection processing exploiting its temporal, spatial and chromatic characteristics. This fire detection technique uses common video surveillance cameras, operating in visible spectrum, that are available at low cost or are already installed in the indoor scenario. Figure 1 shows a possible application scenario where the proposed solution is integrated both with pre-existing CCTV surveillance (using the already installed video cameras) and fire suppression systems with digital connections (standard connections like Ethernet or USB or CAN between the subsystems). Frame rate (fps) of the test videos is from few fps to 30 fps and data format is from QCIF (176x144) to VGA (640x480), and it was implemented in real-time in a low-cost DSP platform with a board size of 10 cm per side.

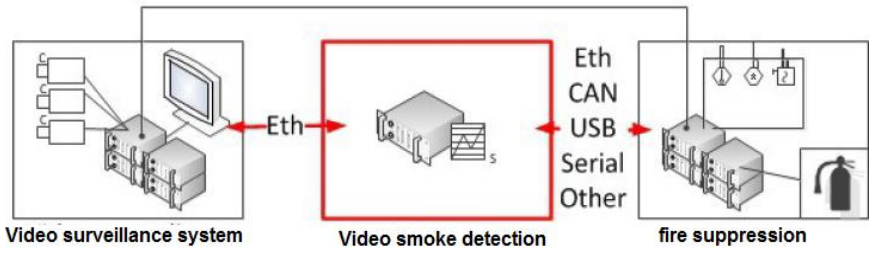

Figure 1: Integration of the video based smoke detector with pre-existing surveillance and fire suppression system

C. *A Probabilistic Approach for Vision Based Fire Detection in Videos*

In this paper [3], they proposed and analyzed a new method for identifying fire in videos. In contrast, this method can be applied to both surveillance and automatic video classification for retrieval of fire catastrophes in databases of newscast content. It analyzed the frame-to-frame changes of specific low-level features describing potential fire regions. These features are color, area size, surface coarseness, boundary roughness, and skew within estimated fire regions. Their objective was to determine if fire occurs in the frame, for the color-based detection they used the *YCbCr* color space instead of the *RGB* space.

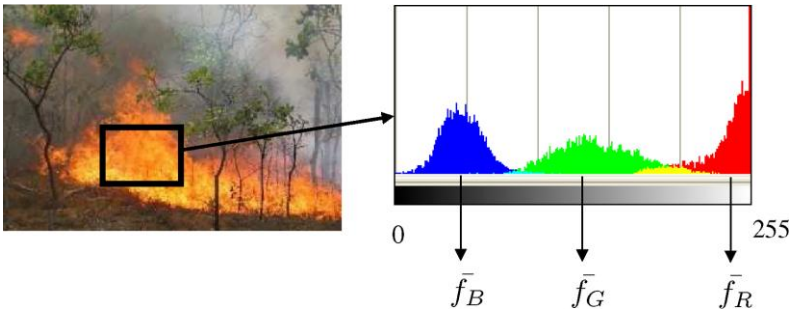

Figure 2 Histogram of a fire region inside the black square, for the red, green, and blue channels

D. *Real-time Fire Detection for Video Surveillance Applications using a Combination of Experts based on Color, Shape and Motion*

In [4] they proposed a method able to detect fires by analyzing the videos acquired by surveillance cameras. Two main novelties have been introduced: first, complementary information, respectively based on color, shape variation and movement of the fire, are combined by a multi expert system. Second, a novel descriptor based on a bag-of-words approach has been proposed for representing motion. Multi Expert System (MES) is used to make the decision by combining the opinions of the different individual classifiers. Objects moving in the scene are first detected by using the algorithm they proposed: a model of the background is maintained and properly updated; a background subtraction strategy was applied to obtain the foreground mask (Foreground mask extraction).Finally, the blobs were obtained using connected component labeling analysis (Connected component labeling). Three different experts have been introduced for evaluating the blobs: the first is based on color (Color evaluation, hereinafter CE); the second analyzes the shape of the blobs detected in the current frame with respect to the ones detected in previous frame (Shape

variation, hereinafter SV); the third evaluates the movement of the blobs in two consecutive frames (Movement evaluation, hereinafter ME). The decisions taken by the experts are combined by a MES classifier based on a weighted voting rule, which finally assigns a class to each blob.

E. Optical Flow Estimation for Flame Detection Videos

This paper proposed a set of motion features based on motion estimators. The key idea in [5] consists of analyzing the characteristics of fire like turbulent, fast, fire motion, and the structured, rigid motion of other objects. Two optical flow methods are specifically designed for the fire detection task: optimal mass transport models fire with dynamic texture, while a data-driven optical flow scheme models saturated flames. Then, characteristic features related to the flow magnitudes and directions are computed from the flow fields to discriminate between fire and non-fire motion. Distinguish the fire from other types of motion estimators are employed. Using the obtained motion fields it the motion features are detected easily. These features reliably detect fire and reject non-fire motion, as demonstrated on a large dataset of real videos

F. Spatio Temporal Flame Modeling and Dynamic Texture Analysis for Automatic Video-Based Fire Detection

In [6] Dimitropoulos proposed a computer vision approach for fire-flame detection to be used by a fire monitoring system. At first the fire regions in a frame are defined based on a non-parametric model the background subtraction and color analysis were done. Subsequently, the fire behavior is modeled by employing various Spatio-temporal features while dynamic texture analysis is applied in each candidate region using linear dynamical systems and a bag of systems approach. The Spatio-temporal consistency energy of each fire region is estimated by exploiting prior knowledge about the possible existence of fire in neighboring blocks from the current and previous video frames. As a last step, a two-class SVM classifier is used to classify the candidate regions. Experimental results have shown that this method outperforms existing state of the art algorithms.

An algorithm for real time video based flame detection was proposed. By modeling both the behavior of the fire using various Spatio-temporal features and the temporal evolution of the pixels' intensities in a candidate image block through dynamic texture analysis, they can have high detection rates, while reducing the false alarms caused by fire-colored moving objects. The use of spatiotemporal consistency energy increases the robustness of the algorithm by exploiting prior knowledge about the possible existence of fire in neighboring blocks from the current and previous video frames. Experimental results with thirty seven videos containing actual fire and moving fire colored objects showed that the proposed algorithm outperforms existing flame detection algorithms. This method outperforms with an average true positive rate of 99.17%, while it didn't produce any false positive due to the coupling of spatiotemporal modeling and dynamic texture analysis.

G. Fire Detection Mechanism using Fuzzy Logic

The work presented in this paper expressed the idea of implementing Fuzzy Logic on the information collected by sensors. This collected information will be passed on to the cluster head using Event Detection mechanism. Thus multiple sensors are used for detecting probability of fire as well as direction of fire. Each sensor node consists of multiple sensors that will sense temperature, humidity, light and CO density for calculating probability of fire and azimuth angle for calculating the direction of fire. It will improve accuracy of the detection system, as well as reduce the false alarm rate.

An event detection mechanism for detection of fire and fuzzy type-2 approach for calculating probability as well as direction of fire is proposed. Thus, the proposed forest fire detection handles the uncertainty present in the data effectively and gives the best results with very low false alarm rate. The decision based on this approach is more accurate. Furthermore, the results obtained are more accurate then the results obtained from type-1 fuzzy system. The membership functions and the parameters can be changed and modified as required. Rules also could be altered and adjusted according to parameters for further extending the work on this model.

H. Real Time Fire Detection in Live Video Surveillance

This paper proposed a fire detection technique using video surveillance in indoor scenarios. A vision based smoke and fire detection is an innovative technique operating in indoor scenarios. There are many visual obstacles like moving people, colored objects similar to fire, that may cause false alarm. The method of using video for the fire detection is to monitor the fire accidents over wide area. Current fire and flame detection algorithms are not only based on the use of color and motion regions, but also analyze the motion in live video. They wish that computers can automatically observe and diagnose images. The edge of an image is the most basic feature. Therefore, edge detection is one of the key research works in image processing using MATLAB software.

The edge detection method used here is Sobel Perwitt, Roberts and Laplacian. The LoG and canny edge detection techniques which have been proposed and it uses Gaussian function to smooth or do convolution to the original video frame. This paper mainly used the Sobel operator to do edge detection processing in the video frames. It is clear that the edge detection is an effective tool and its anti-noise performance is very strong and accurate.

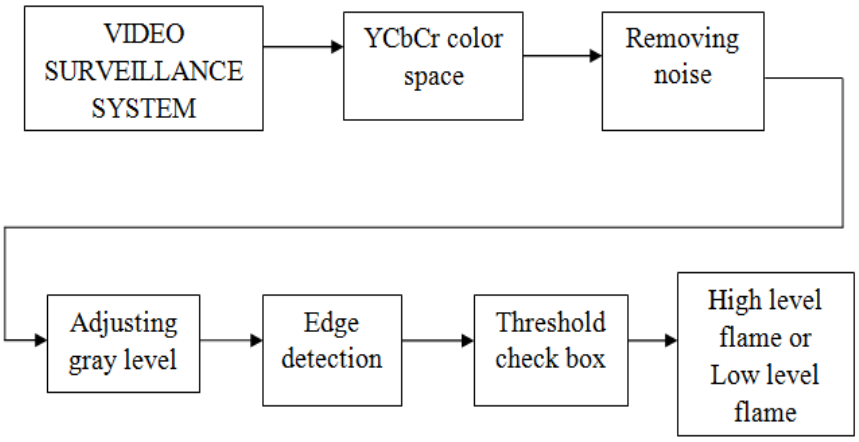

Figure 3 Fire detection using video surveillance system

In this paper, a fire detection system using an integration of several edge detection techniques based on information about color, shape and flame movements. This approach has been tested in several database trained from both live videos and the recorded videos. The frame dimensions for each edge detection technique is nearly from 372×208 to 640×480. The frame rate of live video is about 15 to 20 frames/s, for recorded videos frame rate is about 15 to 30 frames/s. The simulation results of detecting low level flame, high level flame and for fire detection in live videos is shown in the figures 11, 13 and 14 respectively. These results demonstrate that the neural network detector successfully detects edges. This experiment is done using webcam with a 1.3 megapixel CMOS lens, capable of up to a 1280 x 1024 resolution with the time of execution 50 s to 60 s.

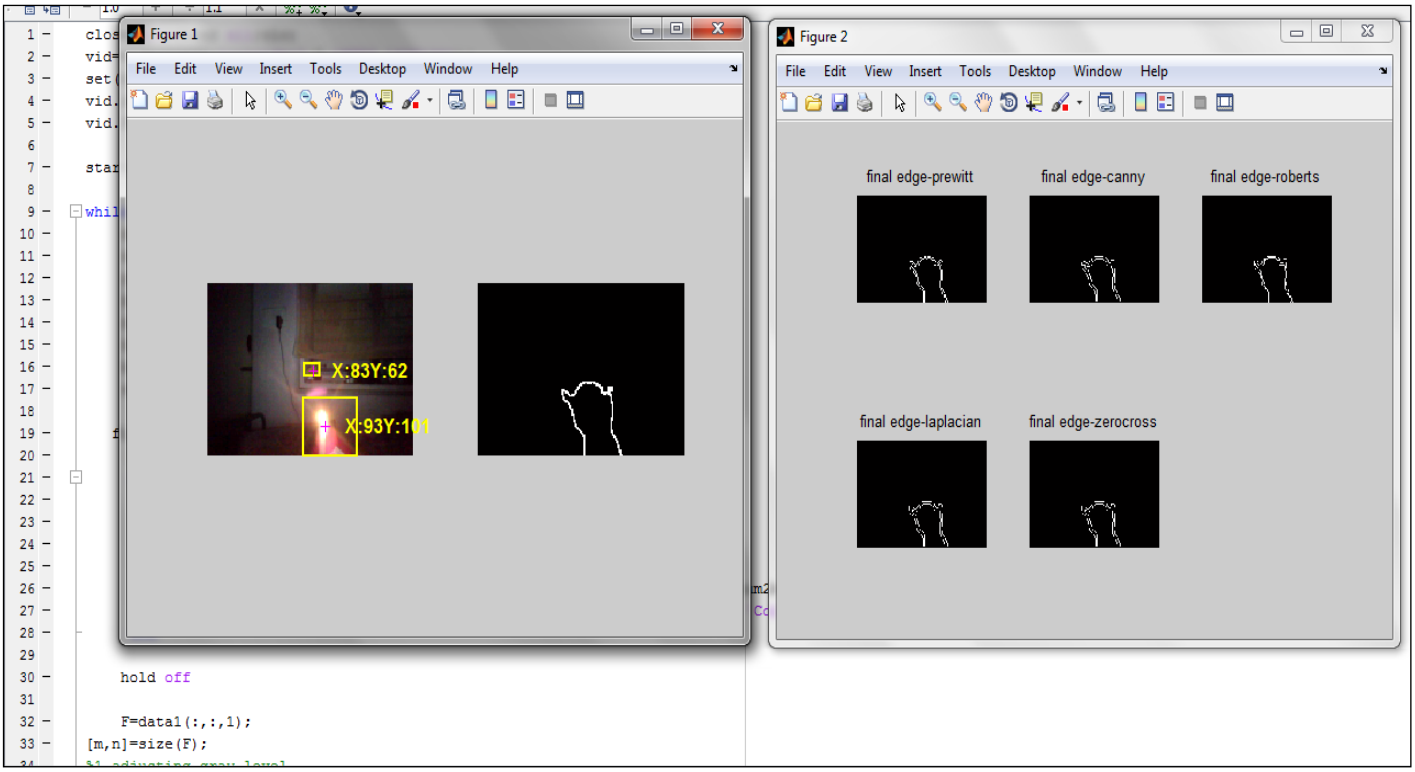

Figure 4 Result of fire detection in live video

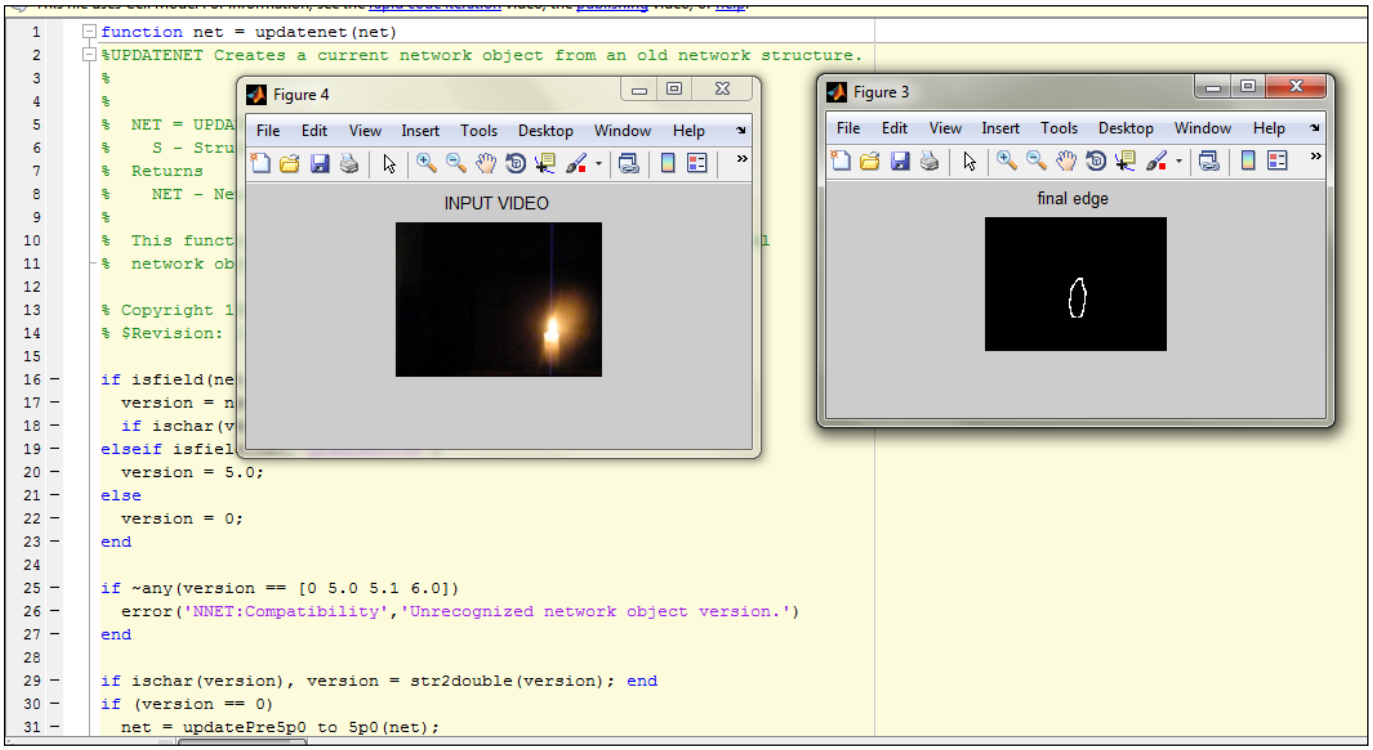

Figure 5 Process of detecting low level flame

The experiment was done using low level flame video recorded using camera. For recorded video the frame rate is more than 30 frames/s. Width by height ratio of the video is about 320×240. Simulation results for the high level flame were detected and results are shown in the Figure 5 & Figure 6**.** The result of fire detection in live video is shown in the Figure 4.

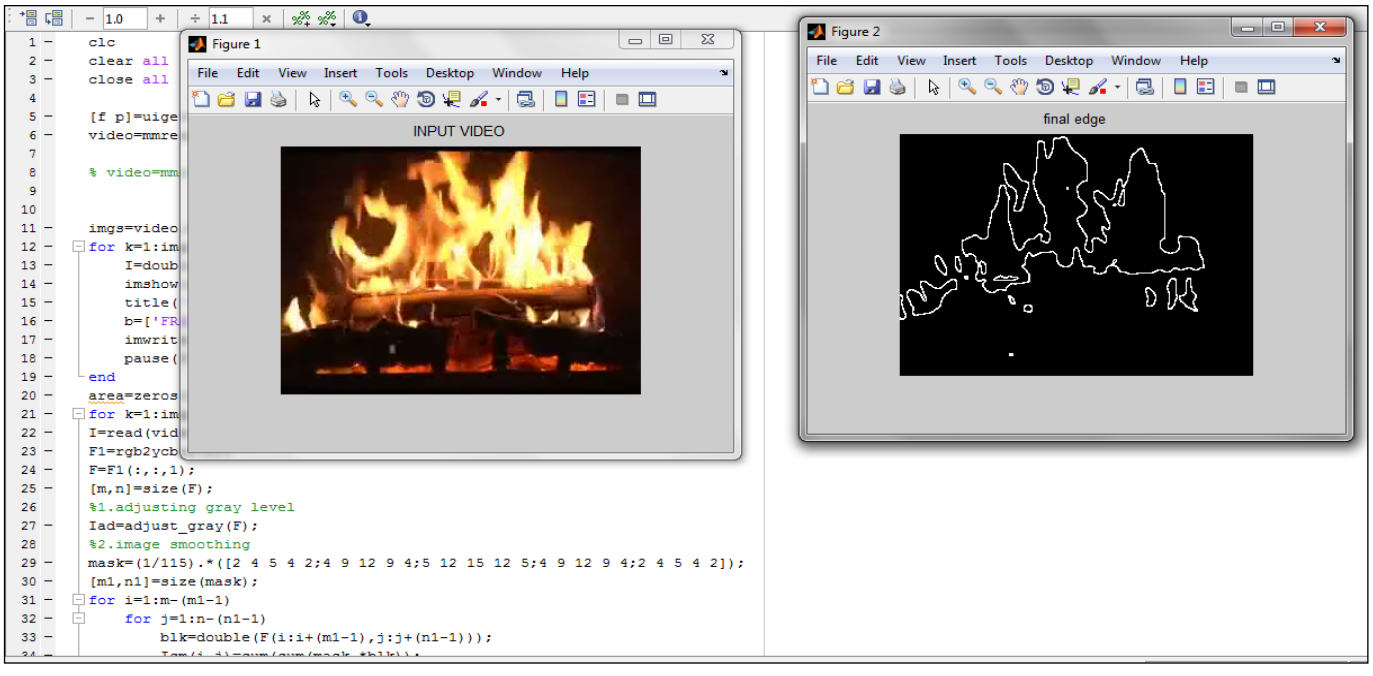

Figure 6 Detecting final edge for high level flame

Table 1 Comparison of various fire detection techniques

SL NO	TITLE	TECHNIQUE USED	MERITS	DEMERITS
[1]	**Real-time Fire Detection for Video Surveillance Applications using a Combination of Experts based on Color, Shape and Motion**	Multi Expert System (MES) [1]	Combining several classifiers to obtain a more reliable decision	Runs in real time at a frame rate of about 3 frames/s on images at a resolution of 320x240
[2]	**Advanced Real Time Fire Detection in Video Surveillance System**	Flame region can be extracted simply by its color information [2]	Background illumination change and scene variation can be eliminated effectively	The input sequence is captured by web camera at 5 frames/s
[3]	**Real-time Imaging Acquisition and Processing System to Improve Fire Protection in Indoor Scenarios**	Fire detection in a low cost DSP- based platform [3]	Customized hardware board was developed	Missed detection and false alarms
[4]	**A Probabilistic Approach for Vision Based Fire Detection in Videos**	Fire detection using Spatial Distribution [4]	Detection metric based on color for fire detection in videos.	Increasing the number of false-negatives
[5]	**Optical Flow Estimation for Flame Detection Videos**	Optical flow methods are used.[5]	Use of motion estimators to distinguish fire from other types of motion	False detections are observed in the presence of significant noise
[6]	**Spatio Temporal Flame Modeling and Dynamic Texture Analysis for Automatic Video-Based Fire Detection**	Spatio-temporal feature and SVM classifier methods are employed.[6]	Spatio-temporal features and the temporal evolution of the pixels.	High computational cost required.
[7]	**Fire Detection Mechanism using Fuzzy Logic**	Fuzzy Logic technique, Event Detection mechanism [7]	Multiple sensors are used for detecting probability of fire as well as direction of fire.	Using sensor makes the system cost high and it takes more time.
[8]	**Real time fire detection in live video surveillance**	Experts based on color, shape and motion	Fire detection is possible in live video surveillance	False detection due to background illumination.

3. CONCLUSION

In this survey fire detection was done by using multiple experts based on information about color of the fire, shape variations in the consecutive frames and flame movements. Using the image processing technique real time fire detection reduces the cost of the hardware and it is applicable on both indoor and outdoor scenarios. This paper leads to yield better output accuracy in the fire detection process.

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