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Detecting fire and flame images using an auto adaptive edge-detection algorithm

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Abstract— **In this project edge detection for fire and flame with fuzzy using canny is implemented. Two basic phases of edge detection i.e. Global contrast intensification and local fuzzy edge detection are first explained and is then merged with fuzzy Canny operator for better results specially for noisy images and low contrast images. The software used for the observation of edges in digital images is by using MATLAB software (ToolBox) because of its efficiency and convenience for handling images for Image Processing. Initially, first-order linear filters constitute the algorithms most widely applied to edge detection in digital images but they don't allow good results to be obtained where the contrast varies a lot, due to non-uniform lighting, as it happens during acquisition of most part of natural images. This is an improved method over all the existing ones. This method identifies the edges of the flames correctly by removing all the noises in the flames. Some research works shows that the existing methods do not emphasize the continuity and clarity of the flame and fire edges. The proposed method identifies the continuous and clear edges of the flame/fire and produces the alarms accordingly. This process detects outlines of an object and boundaries between objects and the background in the image. An edge-detection filter can also be used to improve the appearance of blurred or anti-aliased image streams. The basic edge-detection operator is a matrix area gradient operation that determines the level of variance between different pixels. The experimental result demonstrates the effectiveness of the algorithm.**

Keywords—edge detection, feature extraction, fire, flame, image edge analysis, image processing.

I. INTRODUCTION

Edge detection

Edge detection is one of the most critical and hot topic for digital images for segmenting images and to improve the quality of the image. The core proposal of most edge detection techniques are based on the local first or second derivative operators, which is used by some techniques to reduce the effects of noise in digital images. Some of the previously developed edge detection methods, such as Prewitt, Sobel and Robert's operators used local gradient method for detecting edges for some specified direction. But these were deficient in controlling noise, which resulted in their degraded performance for blurred or noisy images. Based on the Gaussian filter, Canny proposed a fuzzy Canny edge detection method to answer noise problems and to detect the coarse and superfluous edges in aflame image.

Fuzzy Canny edge detection

In this project, we have projected an approach based on fuzzy- Canny for edge detection that works on both global and local image information for fire and flame detection. Initially, we would use an adapted Gaussian membership function for presenting each pixel in the fuzzy domain. And a universal contrariety intensification operator is used for improving image quality by adjusting its parameters.

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In this process, the pixels which are having more edginess will be decreased. The basic strategy of the Fuzzy Canny edge detection method is to define fire and flame edges clearly and continuously. And it is used to detect the coarse and superfluous edges in a flame image.

A. Flame and fire image representation using Fuzzy logic

- **Adjust the gray level of a flame image**:

The first step is to adjust the gray level of a flame image according to its statistical distribution. Considering a discrete grayscale image x and letting N_i be the number of occurrences of gray level of i, the probability of the occurrence of a pixel of gray level i in the image is N_i P(x(i)) = p(x = i) =, 0 < i < L_n; where L is the total number of gray levels in the image, n the total number of pixels in the image, and P(x (i)) the histogram for pixels with i, normalize to [0, 1].

- **Smoothing the image to eliminate noise:**

The second step is to filter out any noise in the image before detecting and locating any edges. A Gaussian filter can be achieved using a simple mask. Gaussian smoothing is performed using standard convolution methods after a suitable mask is selected.

- **Canny with Gaussian Edge Detection:**

While retaining the advantages of Gaussian filtering is the first derivative of a Gaussian. This operator corresponds to smoothing an image with a Gaussian function and then computing the gradient. The gradient can be numerically approximated by using the standard finite-difference approximation for the first partial derivatives in the x and y directions listed. The operator that is the combination of a Gaussian smoothing filter and a gradient approximation is not rotationally symmetric. The operator is symmetric along the edge and ant symmetric perpendicular to the edge (along the line of the gradient). This means that the operator is sensitive to the edge in the direction of steepest change, but is insensitive to the edge and acts as a smoothing operator in the direction along the edge.

- **Adjust TH and TL for better results:**

Better results are achieved by giving the first pair of TH and TL initial values according to the a priori results of similar flame images and then adjusting the values for a better result. The "better" result is assessed by how many edges there are: The more edge pixels detected in the edge image, the better the parameters are.

The Canny edge-detection algorithm an improved method using the Sobel operator, is known to be a powerful edge detection method. In the second category, edges are detected by searching a second-order derivative expression over the image, usually the zero crossings of the Laplacian or a nonlinear differential expression. In the present research, these common edge-detection methods have been applied with appropriate parameters to process typical flame images. Despite many parameters being finely and appropriately adjusted in the use of these methods, flame edges could not be clearly identified.
A gray tone image R of dimension M x N and L levels for representing any image in fuzzy domain from spatial domain, can be considered as an array of fuzzy singleton sets:

$$R = \{(\mu_{mn}, x_{mn}) \text{ where } m= 1,\ldots.M; n=1,\ldots.N;\} \quad (1)$$

With this every pixel has its own intensity value x_{mn} and with the intensity membership grade μ_{mn} ($0\leq \mu_{mn}\leq 1$) relative to some brightness level in the range [0, L-1].For expressing the properties of fuzzy Membership function is used. The extended Gaussian membership function for simply transformation containing only one fuzzifier is given by

$$\mu_{mn} = G(x_{mn}) \frac{[e^{-(Xmax-Xmn)^2}]}{2fh^2} \quad (2)$$

With G (x_{mn}) is a extended Gaussian function, and x_{max}, x_{mn} are the minimum and (m, n)th gray values resp. A histogram with fuzzy will be used to obtain the number of possible occurrences of gray levels in the fuzzy image. So,

$$R = U \{\mu(x),p(x)\} = \{\mu_{mn}/x_{mn}\} ; \quad m=1,\ldots.,M; n=1,2,\ldots..,N \quad (3)$$

Where $\mu(x)$ is a function i.e. membership of pixel with intensity value of x, and p(x) is the function for the frequency of occurrences of the intensity value x, in the image R. The distribution of p(x) is normalized such that

$$\sum_{x=0}^{L-1} P(x) = 1 \quad (4)$$

Histogram based membership function with which pixels of spatial domain can be represented in fuzzy domain is given as

$$\mu(k) = \frac{[e^{-(Xmax-K)^2}]}{2fh^2} \quad (5)$$

where k varies from 0 to L-1 and the fuzzifier parameter, f_h can be determined as

$$f_h = \frac{\sum_{L=0}^{k-1}(Xmax-K)^4 P(K)}{2\sum_{K=0}^{L-1}(Xmax-K)^2 P(K)} \quad (6)$$

where p(k) specifies the probable occurrences of k in histogram R. In the fuzzy plane, an image with enhanced-contrast is in low perception i.e. will be dark, µ Є [0, 0.5] or high perception i.e. bright µ Є [0.5, 1] values. The pixels which approximates to µ=0.4 do not belong to any of the two classes (bright/dark) focuses on the fuzzy boundary and hence they may contain edges. We will first enhance the image using non linear intensification function as image detection is non linear in nature. NINT [µ(k)] having 3 defined parameters, which are: crossover point *xc*, intensification operator t and the fuzzifier *fh* which are used as

$$\mu'(k)= NINT[\mu(k)] = 1/(1+\exp[-t(\mu(k)-x_c)]) \quad (7)$$

With t used to control the shape of the sigmoid function and x_c is initialized to the default value 0.5. Other parameters are adjusted through µ(k) while t will remain fixed to control the level of contrast enhancement in the image.

B. Steps of fuzzification in Canny edge detection

- Intervolve the image with the derivation of a Gaussian.
- Then take the non-maxima suppression to the gradient magnitude image.
- Use two thresholds T1 > T2
- Class = {edge if magnitude > T1 Candidate if magnitude > T2}
- Hysteresis: All the candidates are acting as the neighbors in the gradient direction of an edge recalled as an edge.

II. Fuzzy Based Canny Edge Detection On Motion Video

The algorithm runs in 5 separate steps:

- Smoothing: Blurring of the image to remove noise.
- Finding gradients: The edges should be marked where the gradients of the image has large magnitudes.
- Non-maximum suppression: Only local maxima should be marked as edges.
- Double thresholding: Potential edges are determined by thresholding.

Smoothing:

It is inevitable that all images taken from a camera will contain some amount of noise. To prevent that noise is mistaken for edges, noise must be reduced. Therefore the image is first smoothed by applying a Gaussian filter.

Finding gradients:

The Canny algorithm basically finds edges where the grayscale intensity of the image changes the most.

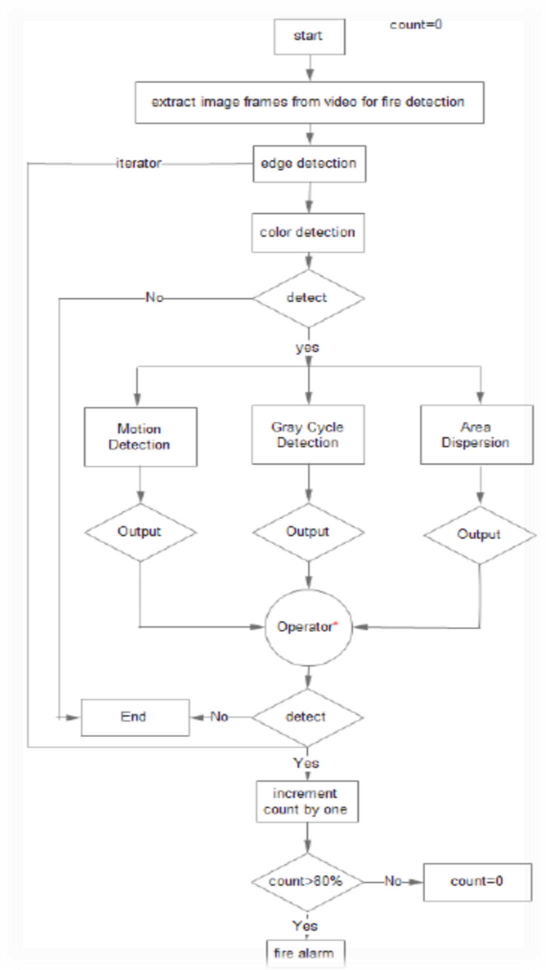

Figure 1 Flow chart

are found by determining gradients of the image. Gradients at each pixel in the smoothed image are determined by applying .

Non-maximum suppression:

The purpose of this step is to convert the "blurred" edges in the image of the gradient magnitudes to "sharp" edges pixel in the gradient image:

- Gradient direction to the nearest 45◦ corresponding to the use of an 8-connected neighborhood is rounded.

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- The edge strength of the current pixel with the edge strength of the pixel in the positive and negative gradient direction is compared.

Almost all pixels have gradient directions pointing north. They are therefore compared with the pixels above and below. The pixels that turn out to be maximal in this comparison are marked with white borders. All other pixels will be suppressed. The edge strengths are indicated both as colors and numbers, while the gradient directions are shown as arrows. The resulting edge pixels are marked with white borders.

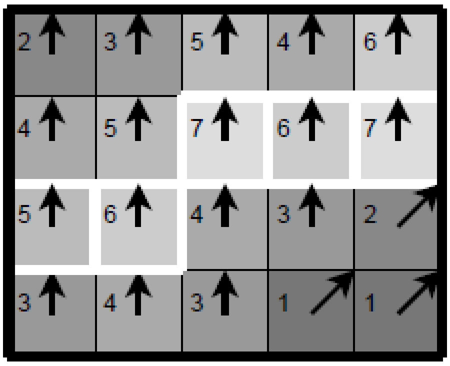


Figure 2 : Non- maximum suppression

Double thresholding:

The edge-pixels remaining after the non-maximum suppression step are (still) marked with their strength pixel-by-pixel. Many of these will probably be true edges in the image, but some may be caused by noise or color variations for instance due to rough surfaces. The simplest way to discern between these would be to use a threshold, so that only edges stronger that a certain value would be preserved. The Canny edge detection algorithm uses double thresholding. Edge pixels stronger than the high threshold are marked as strong; edge pixels weaker than the low threshold are suppressed and edge pixels between the two thresholds are marked as weak.

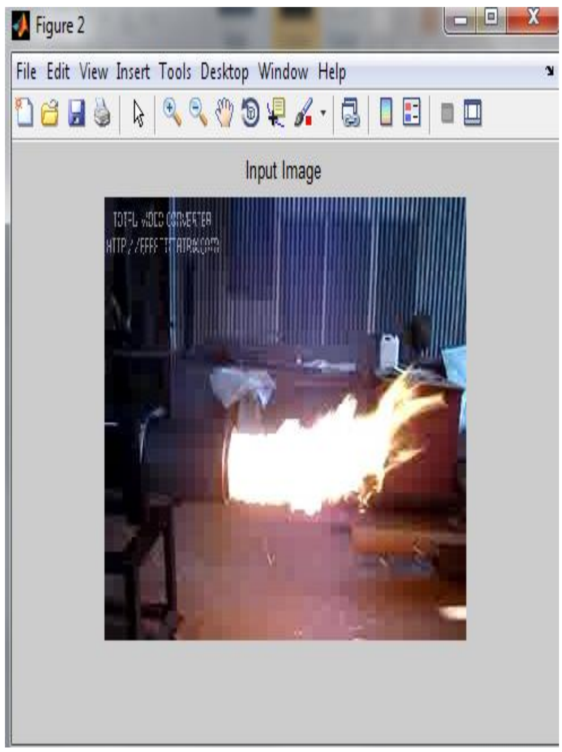
Edge tracking by hysteresis:

Strong edges are interpreted as "certain edges", and can immediately be included in the final edge image. Weak edges are included if and only if they are connected to strong edges. The logic is of course that noise and other small variations are unlikely to result in a strong edge (with proper adjustment of the threshold levels).

Thus strong edges will (almost) only be due to true edges in the original image. The weak edges can either be due to true edges or noise/color variations. The latter type will probably be distributed independently of edges on the entire image, and thus only a small amount will be located adjacent to strong edges. Weak edges due to true edges are much more likely to be connected directly to strong edges.

III. SCREEN SHOTS

Compared images



Input image

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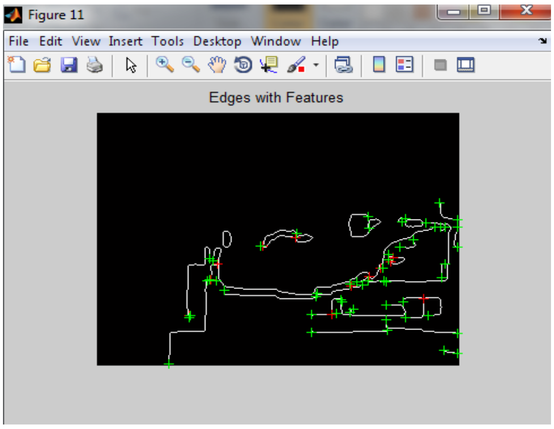

Edges with features

to answer noise problems, for the images involved with the first order derivatives for smoothing in the local gradient direction which was followed by edge detection by thresholding the images. Some other algorithms which were based on Non-linear filtering techniques for edge detection, which works by associating a small area of adjacent pixels with related brightness to each center pixel. Also during recent years, techniques have been proposed that uses edge detection as a fuzzy problem. Some local and global approaches has used morphological edge extraction method using Fuzzy logic. It used both global and local image information for fuzzy categorization and classification based on edges. In this project, we have projected an approach based on fuzzy-Canny for edge detection that works on both global and local image information for fire and flame detection. Initially, we would use an adapted Gaussian membership function for presenting each pixel in the fuzzy domain. After which, a universal contrariety intensification operator is used for improving image quality by adjusting its parameters. In this process, the pixels which are having more edginess will be enhanced and on the other hand the pixels with less edginess will be decreased. The entropy optimization function with gradient descent function gives new optimized parameters of contrast/pixel enhancement. In the second phase of edge detection which will involve the edge detection with local image information by a local fuzzy mask, similar to the one used.Thereafter, simple thresholding method based on experimental observations using MATLAB which will be followed by the last step i.e. Canny edge detection, which will be used to link the edges obtained and results for very low contrast and noisy images as discussed in the project.

After the flame characteristics are analyzed, a new flame edge-detection method has been developed and evaluated in comparison with conventional methods. Experimental results have demonstrated that the algorithm developed is effective in identifying the edges of irregular flames. The advantage of this method is that the flame and fire edges detected are clear and continuous. Furthermore, with the change of scenarios, the parameters in the algorithm can be automatically adjusted. The clearly defined combustion region lays a good foundation for subsequent quantification of flame parameters such a flame volume, surface area, flame spread speed, and so on. It is envisaged that this effective flame edge-detection algorithm can contribute to the in-depth understanding and advanced monitoring of combustion flames. Meanwhile, the algorithm provides a useful addition to fire image processing and analysis in fire safety engineering. The work presented was aimed for the processing of flame and fire images captured in laboratories. Further work is required to evaluate the performance of the algorithm in real-life flame detection scenarios.

Table of comparision

The table of comparison shows the comparison of the existing operators and the proposed operator. The Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) of the Sobel, Prewitt, Log, Canny and Fuzzy Canny is compared. By using the proposed method called Fuzzy Canny edge detection the mean square error is reduced and the clear and continuous image of the flame is obtained.

Table of comparison of operators

OPERATORS	PSNR	MSE
Roberts	**7.3186**	**12057**
Sobel	**7.3200**	**12053**
Prewitt	**7.3200**	**12053**
Log	**7.3243**	**12041**
Canny	**7.3232**	**1204**
Fuzzy Canny	**30.3923**	**60**

After the flame characteristics are analyzed, a new flame edge detection method called Fuzzy Canny edge detection method has been developed and evaluated in comparison with conventional methods. Experimental results have demonstrated that the algorithm developed is effective in identifying the edges of irregular flames. The advantage of this method is that the flame and fire edges detected are clear and continuous. Furthermore, with the change of scenarios, the parameters in the algorithm can be automatically adjusted. It is envisaged that this effective Fuzzy Canny edge detection algorithm can contribute to the in-depth understanding and advanced monitoring of combustion flames. Meanwhile, the algorithm provides a useful addition to fire image processing and analysis in fire safety engineering.

The future work is an auto adaptive edge detection using optimal spatial frequency filter. In order to detect the occurrence of fire, both flame and smoke need to be analyzed. The optimum filter is very effective for detecting blurred and noisy edges. Our purpose of the future project is to develop an occurrence of fire based on video images and to give more optimized results in detection of flame and fire. Finally, we will compare the performance of the optimum edge detection filter with other edge detection filters using a variety of input images.

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