

Continuous Fire Edge Detection Algorithm

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Abstract—We have to identify a region where there is occurrence of thermo chemical reaction and where there is no thermo chemical reaction for the determination of fire or flame edges. We can use image based flame detectors for detection of fire and can trigger an alarm to the fire fighters instead of using conventional sensors where the alarm is not triggered until the particles reach the sensors to activate them. The advantage of image based flame detectors is it reduces the processing time thus making early fire detection compared to conventional sensors. The CCTV (Closed Circuit Television) or Internet Protocol (IP) cameras can be fixed in any building to capture the fire image from the video whereas the sensors face the proximity problem. The advantage of the proposed edge detection algorithm is that it detects the fire images clearly and continuously, reduces the unnecessary noise thus reducing the processing time and making fire analysis easier where the conventional edge detection methods fail to do so. The proposed algorithm also detects the edges of turbulent flames.

Keywords—Fire, flame, CCTV, edge detection, clear, continuous, shape.

I. INTRODUCTION

We can use image based flame edge detectors in video for detection of fire and can trigger an alarm to the fire fighters instead of using conventional point smoke and fire detectors where the alarm is not triggered until the particles reach the sensors to activate them. The advantage of image based flame detectors [1], [2] in video is it reduces the processing time thus making early fire detection compared to conventional sensors.

The CCTV (Closed Circuit Television) or Internet Protocol (IP) cameras can be fixed in any building to capture the fire image from the video where as the sensors face the proximity problem and another advantage for image based flame edge detectors in video is that they can be useful to detect fire in large auditoriums, tunnels and atriums where the conventional point smoke and fire detectors fail to do so.

Video based flame detection systems also have several more advantages. They are cost of installation is lower and response time is faster. Lower installation cost is due to the fact that the flame detection system has cameras and nowadays surveillance is done with CCTV cameras in industries. Faster response time is because the flame detection systems will not wait until the combustion product reaches in case of a sensor.

The mechanism of flame detection system is as follows: Initially we install the system and give predetermined

training to the system and also store certain fire images with their characteristics i.e. color information on the system database. When a CCTV camera captures an image, it is immediately given to image processing software and the image is compared with database of the system and color information. If the image is confirmed as a fire, immediately by automation the alarm is on and the information is provided to fire fighters. If the image is not confirmed as a fire i.e. in case of a false alarm, the personnel from the control room can have the confirmation without rushing to the fire or flame location.

In power generation industry and laboratory research, quantitative flame monitoring is used to keep a check on combustion efficiency and pollutant emissions. As a result of this, advanced flame imaging technologies have gained importance in the recent years.

Image based flame edge detectors in video can be used instead of conventional edge flame detection systems due to the following advantages. The first and the foremost step in flame and fire image processing is edge detection, which paves the way for other processing. The flame or fire edges can be determined by identifying a region between the areas with a thermo chemical reaction and the areas without a thermo chemical reaction. There are several advantages in edge detection. First, the flame edges are used to find parameters like shape, size, location and stability of the fire. Second, as we define the flame edges, the unwanted information such as background noise are filtered out, thereby reducing the amount of data processing and time. Third, edge detection can be helpful in multiple-flame monitoring in industrial furnaces by segmenting a group of flames.

There are many methods developed for edge detection of flames, which have limitations like lack of clarity and continuity in the flame edges and also mismatch of shape when compared to actual flame.

Conventional edge detection methods often extract edges from non trivial images which are often prone to fragments i.e. curves of edges are disconnected or melted or false edges that do not correspond to significant information are often shown.

To overcome these limitations, a new computing algorithm is presented in this paper to detect flame and fire edges clearly and continuously. It detects the coarse and superfluous edges in the flame image and then identifies the edges and removes the irrelevant artifacts. This algorithm is auto-adaptive in the sense that, with the change in scenarios, the parameters in the algorithm can be

automatically adjusted. The algorithm also helps in advanced monitoring of combustion flames

II. EDGE DETECTION CONVENTIONAL METHODS

An edge is a local feature that within a neighborhood separates two regions in each of which the gray level is more or less uniform with different values on the two sides. Ideal edge will have a step like cross section and realistic edge which has a shape of ramp function corrupted by a noise.

An edge is a boundary between two edge regions having distinct gray levels. If we draw intensity profile along the horizontal line, the transition is not abrupt but it is gradual. This is because of Sampling and Quantization. The first and the second derivatives can be used for representing the edges.

The first derivative is positive at the leading edge and is negative at the trailing edge. The second derivative is positive at dark side of the edge and negative on the bright side of the edge and it is very sensitive to the noise and cannot be used for edge detection. Zero crossing determines the location of the edge.

There are several edge detection methods [3], [4], [5], [6].

They are classified as follows:

- (1) Prewitt method
- (2) Sobel method
- (3) Roberts method
- (4) Laplacian method
- (5) Canny method

(1) Prewitt method: It is a one dimensional operator. It is known as normal derivative. It identifies the part of the flame edge. With Prewitt method we can't find the strength and direction of an edge at a particular location. Prewitt Edge Operator can't give better results as compared to Sobel Edge Operator.

The Prewitt operator gradients are defined as

$$M_x = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad (2.1)$$

$$M_y = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad (2.2)$$

(2) Sobel method: It is a one dimensional operator. It can find the strength and direction of an edge at a particular location. It is used for averaging effect to reduce noise and gives better results compared to Prewitt. It puts more weight on the center pixels. It identifies the part of the flame edge.

The Sobel operator gradients are defined as

$$M_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (2.3)$$

$$M_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (2.4)$$

(3) Roberts method: Used to estimate M_x and M_y . The disadvantage of this method is that it cannot recognize 45° . It identifies the part of the flame edge.

The Roberts operator gradients are defined as

$$M_x = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \quad (2.5)$$

$$M_y = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \quad (2.6)$$

(4) Laplacian method: It is a two dimensional operator. It is not used because it is very sensitive to noise and it leads to double lines at every transition. It is used for enhancement of image and can be used in finding edges. It can be used to determine whether edge is quantized in left side or right side. It is used for accurately finding out the location of edge. It is used to reduce the effect of noise.

The Laplacian operator gradients are defined as

$$M_1 = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad (2.7)$$

$$M_2 = \begin{bmatrix} -1 & 0 & -1 \\ 0 & 4 & 0 \\ -1 & 0 & -1 \end{bmatrix} \quad (2.8)$$

$$M_3 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad (2.9)$$

$$M_4 = \begin{bmatrix} 1 & 0 & 1 \\ 0 & -4 & 0 \\ 1 & 0 & 1 \end{bmatrix} \quad (2.10)$$

(5) Canny method: It is a powerful edge detection method. It is an improved method using the Sobel Edge Operator. Canny Edge Operator wrongly identifies edges that are not the edges of the main flame.

III. CONTINUOUS FIRE EDGE DETECTION ALGORITHM

Step (1) Conversion of Original Color or RGB Image to Resized Image: Initially resize the original color or RGB image in order to reduce the processing time.

Step (2) Conversion of Resized Image to Grayscale Image: After resizing the original color image, convert the resized image to grayscale image. As the resized image has three frames i.e. RGB, this will take a lot of processing time. So the resized image is converted to grayscale image where the grayscale image has only single frame so that the processing speed will be greatly reduced.

Step (3) Normalization of Grayscale image: Normalization is a process that changes the range of intensity values. Normalization stretches an image pixel values to cover the entire pixel value range i.e. (0-255). *adaphisteq* performs Contrast-limited Adaptive Histogram Equalization (CLAHE) on the intensity image I.

adaphisteq enhances the contrast of images by transforming the values in the intensity image. Unlike HISTEQ, it operates on small data regions (tiles), rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the specified histogram.

The neighboring tiles are then combined using bilinear interpolation in order to eliminate artificially induced

boundaries. The contrast, especially in homogeneous areas, can be limited in order to avoid amplifying the noise which might be present in the image.

Step (4) Gaussian Smoothing: Before locating and detecting the edges we have to filter out the noise present in an image. This is achieved by a simple 5X5 Gaussian mask. A Gaussian filter is designed by using this mask. When the desired mask is selected Gaussian smoothing is done using standard methods of convolution.

When the width of the Gaussian mask is larger, the detector's sensitivity will be smaller for the background noise present in the flame or fire image. The localization error present in the edges of detected fire or flame slightly increases with the Gaussian width because of the fact that detected fire or flame edges are made precise by the larger mask. Figure 1 explains the Gaussian function discrete approximation.

	2	4	5	4	2
	4	9	12	9	4
	5	12	15	12	5
(1/115)x	4	9	12	9	4
	2	4	5	4	2

Figure 1: Gaussian function discrete approximation

Step (5) Applying the Sobel edge operator: At this stage we find out the gradients for all the pixels present in an image for finding edges. Finding gradients will ensure that higher gray level contrast regions will be highlighted and the algorithm ensures that it finds out the edges present in these regions and the pixels which are at the lower level of gradients will be suppressed.

We define two thresholds T_H and T_L i.e. high and low threshold respectively. If the calculated value of the gradient magnitude is greater than T_H , it is confirmed as an edge. If the gradient magnitude lies in between T_H and T_L values, the gradient magnitude is set to zero unless there is no path from the gradient pixel to another pixel with a gradient value greater than T_L .

The 2-D spatial measurement of gradient for an image is performed by the Sobel edge operator. Thus the edge strength or absolute gradient magnitude approximation can be found out by this operator.

The Sobel edge operator estimates the gradients in x-direction (rows) and also y-direction (columns).

$$M_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (3.1)$$

$$M_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (3.2)$$

M_x and M_y denote the expressions for the Sobel edge operator.

Step (6) Adjusting the threshold: We first give pair of T_H and T_L values based on a priori results of similar fire or flame edges and we obtain the better result by adjusting T_H and T_L values. We can assess better result by finding out

the number of edges. We will obtain the better parameters if and only if the detected edge image has more edge pixels.

For the optimized threshold, a preliminary edge image (PEI) is obtained from the original fire or flame image.

Step (7) Unrelated removal of edges in PEI:

(i) PEI point selection as a search center: Select any random edge point from the PEI and allocate a new temporary edge image and plot the point onto it.

(ii) Finding neighbors for the search center: By using the selected point as the center, search in a 3X3 area and if the neighborhood pixels are detected as edge pixels, then store the location for these neighborhood pixels. We consider three cases for the eight neighboring pixels of the center pixel.

(a) The point selected is an isolated point if there is no neighboring pixel. The point must be removed from the PEI and the search will be terminated and proceed to step 7 (iv).

(b) The selected point is an endpoint if there is one neighboring pixel. The point should be immediately removed from the PEI and added to the temporary edge image and plotted to the endpoint list. Again initiate a new search from the found neighbor and proceed to step 7 (iii).

(c) If two or more neighboring pixels are found for the search center, then set one of the found neighboring point as a search center and perform a new search. At the same time, store the locations of other pixels as unchecked conjunction points and proceed to step 7 (ii).

(iii) By checking all the conjunction points i.e. they are searched as a center then temporary edge image is determined. Then select the longest temporary edge image by calculating the lengths of any two endpoints and proceed to step 7 (iv).

(iv) When all the pixels present in the PEI are moved to the temporary edge image, go to step 8.

Step (8) Obtaining an edge which is clearly defined: In the final edge image, select the pixels of the longest edge and the important criteria for the longest edge is that it should have the original image size.

IV. SIMULATION RESULTS

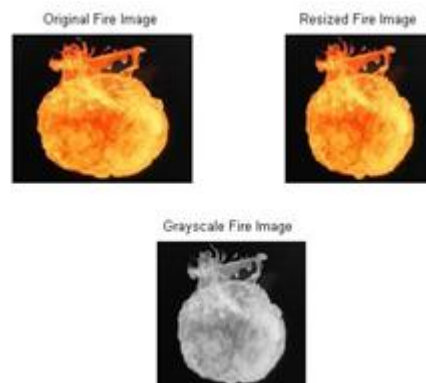


Figure 2: Original, Resized and Grayscale Fire Images

Initially resize the original fire image in order to reduce the processing time. After resizing the original color image,

convert the resized image to grayscale image. As the resized image has three frames i.e. RGB, this will take a lot of processing time. So the resized image is converted to grayscale image where the grayscale image has only single frame so that the processing speed will be greatly reduced. The above stated operations performed are illustrated in Figure 2.

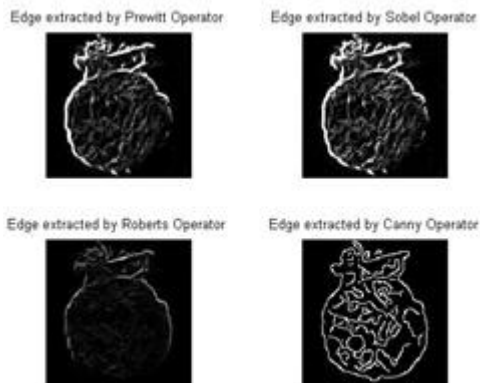


Figure 3: Prewitt, Sobel, Roberts, Canny edge detection methods

Apply the edge detection methods to grayscale image. The Prewitt, Sobel and Roberts edge detection methods give unclear and discontinuous results which makes fire analysis difficult. The Canny edge detection method gives clear and continuous results but with a lot of unnecessary details which makes the Canny edge detection an ineffective method. The above stated operations performed are illustrated in Figure 3.



Figure 4: Laplacian edge detection method

Finally, apply the Laplacian edge detection method to the grayscale image. The Laplacian edge detection method gives clear and continuous results but with lot of unnecessary details. The above stated operations performed are illustrated in Figure 4.

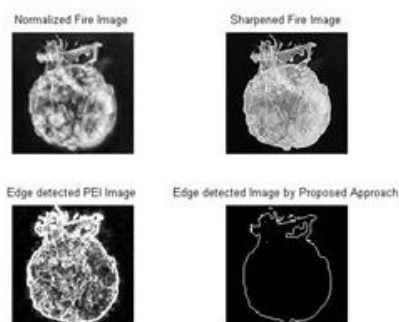


Figure 5: Normalized, Sharpened, PEI, Proposed Approach Images

Apply the Normalization method to the grayscale image. Normalization stretches an image pixel values to cover the entire pixel value range i.e. (0-255). Apply a Gaussian mask i.e. sharpen the normalized image in order to reduce the noise. Apply the Sobel edge detection to normalized image for finding the edges and also adjust the threshold. For the optimized threshold, an Preliminary Edge Image (PEI) is formed. From the PEI, unrelated edges are removed and a clearly defined edge is formed. The above stated operations performed are illustrated in Figure 5.

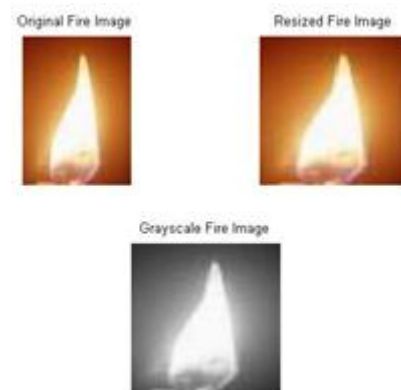


Figure 6: Original, Resized and Grayscale Fire Images

Initially resize the original fire image in order to reduce the processing time. After resizing the original color image, convert the resized image to grayscale image. As the resized image has three frames i.e. RGB, this will take a lot of processing time. So the resized image is converted to grayscale image where the grayscale image has only single frame so that the processing speed will be greatly reduced. The above stated operations performed are illustrated in Figure 6.

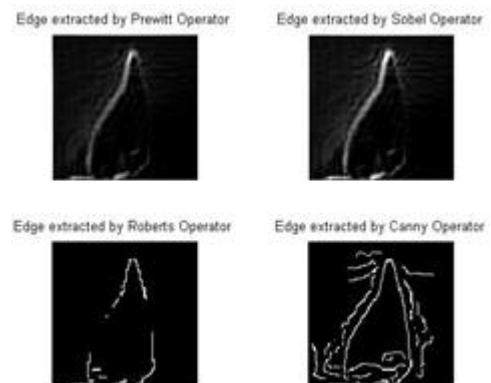


Figure 7: Prewitt, Sobel, Roberts, Canny edge detection methods

Apply the edge detection methods to grayscale image. The Prewitt, Sobel and Roberts edge detection methods give unclear and discontinuous results which makes fire analysis difficult. The Canny edge detection method gives clear and continuous results but with a lot of unnecessary details which makes the Canny edge detection an ineffective method. The above stated operations performed are illustrated in Figure 7.

Edge extracted by Laplacian Operator



Figure 8: Laplacian edge detection method

Finally, apply the Laplacian edge detection method to the grayscale image. The Laplacian edge detection method gives clear and continuous results but with lot of unnecessary details. The above stated operations performed are illustrated in Figure 8.

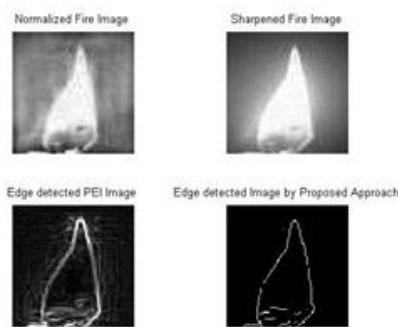


Figure 9: Normalized, Sharpened, PEI, Proposed Approach Images

Apply the Normalization method to the grayscale image. Normalization stretches an image pixel values to cover the entire pixel value range i.e. (0-255). Apply a Gaussian mask i.e. sharpen the normalized image in order to reduce the noise. Apply the Sobel edge detection to normalized image for finding the edges and also adjust the threshold. For the optimized threshold, an Preliminary Edge Image (PEI) is formed. From the PEI, unrelated edges are removed and a clearly defined edge is formed. The above stated operations performed are illustrated in Figure 9.

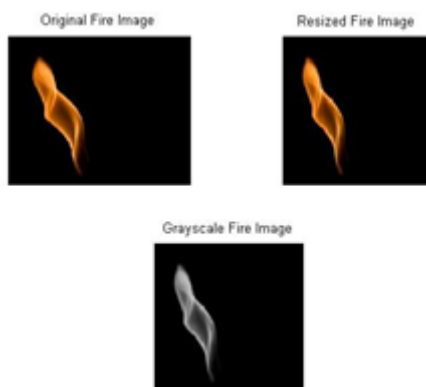


Figure 10: Original, Resized and Grayscale Fire Images

Initially resize the original fire image in order to reduce the processing time. After resizing the original color image, convert the resized image to grayscale image. As the resized image has three frames i.e. RGB, this will take a lot

of processing time. So the resized image is converted to grayscale image where the grayscale image has only single frame so that the processing speed will be greatly reduced. The above stated operations performed are illustrated in Figure 10.

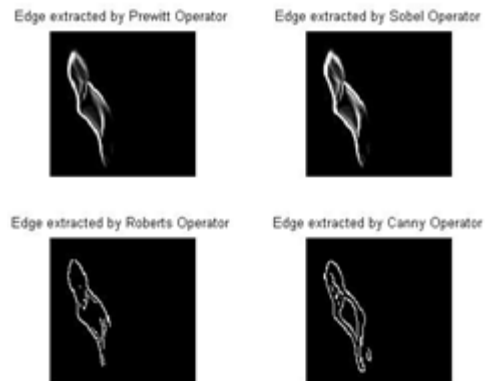


Figure 11: Prewitt, Sobel, Roberts, Canny edge detection methods

Apply the edge detection methods to grayscale image. The Prewitt, Sobel and Roberts edge detection methods give unclear and discontinuous results which makes fire analysis difficult. The Canny edge detection method gives clear and continuous results but with a lot of unnecessary details which makes the Canny edge detection an ineffective method. The above stated operations performed are illustrated in Figure 11.

Edge extracted by Laplacian Operator



Figure 12: Laplacian edge detection method

Finally, apply the Laplacian edge detection method to the grayscale image. The Laplacian edge detection method gives clear and continuous results but with lot of unnecessary details. The above stated operations performed are illustrated in Figure 12.

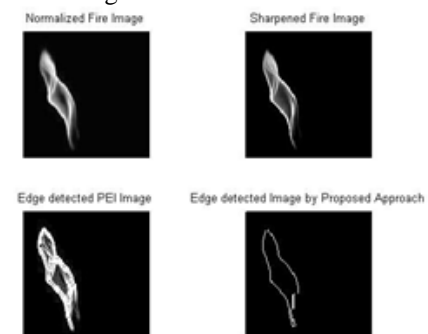


Figure 13: Normalized, Sharpened, PEI, Proposed Approach Images

Apply the Normalization method to the grayscale image. Normalization stretches an image pixel values to cover the entire pixel value range i.e. (0-255). Apply a

Gaussian mask i.e. sharpen the normalized image in order to reduce the noise. Apply the Sobel edge detection to normalized image for finding the edges and also adjust the threshold. For the optimized threshold, an Preliminary Edge Image (PEI) is formed. From the PEI, unrelated edges are removed and a clearly defined edge is formed. The above stated operations performed are illustrated in Figure 13.

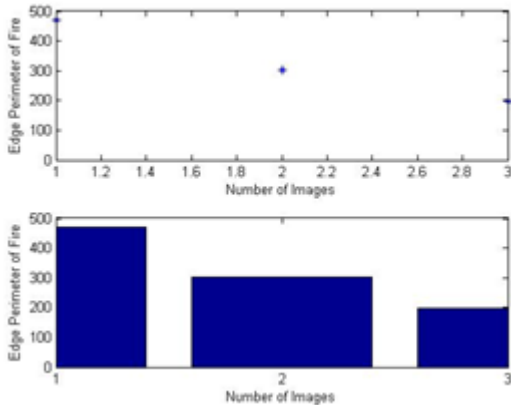


Figure 14: Perimeter versus Number of Images Graphs

The edge perimeter for three images is shown in normal and bar graphs representation in Figure 14. For the first, second and third images, the edge perimeters or number of edge pixels are 472, 302 and 197 respectively. So we infer from the above graph that the first image has rapid intensity variations compared to the second image and third image.

V. CONCLUSION

The algorithm has been successful in identifying the edges of irregular flames or fire clearly and continuously whereas the conventional edge detection methods fail to do so. The algorithm can easily distinguish the flame region from the background. The fire or flame edge detection algorithm helps in identifying the shape of the flame or fire. The algorithm also reduces the processing time through the use of CCTV or IP camera and image processing software unlike the conventional sensors which are not activated unless the particles of combustion reach the sensors.

VI. FUTURE SCOPE

In order to speed up the process of finding proper T_H and T_L , a least mean square (LMS) algorithm can be used which is a class of adaptive filters by finding the filter coefficients. Here the two parameters T_H and T_L will be auto adjusted which saves a lot of computational time.

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