An Efficient Autoadaptive Edge Detection Approach for Flame and Fire Images

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Abstract: The determination of flame or fire edges is the process of identifying a boundary between the area where there is thermo-chemical reaction and those without. It is a precursor to image-based flame monitoring, early fire detection, fire evaluation, the determination of flame and fire parameters. Several traditional edge-detection methods have been tested to identify flame edges, but the results achieved have been disappointing. Some research works related to flame and fire edge detection were reported for different applications; however, the methods do not emphasize the continuity and clarity of the flame and fire edges. A computing algorithm identifies flame and fire edges clearly and continuously. The algorithm detects the coarse and superfluous edges in a flame/fire image first and then identifies the edges of the flame/fire and removes the irrelevant artifacts. The auto-adaptive feature of the algorithm ensures that the primary symbolic flame/fire edges are identified for different scenarios. As the algorithm works for luminous fire/flame images, it is enhanced to effectively detect the edges for non-superfluous images also. Experimental results for different flame images and video frames proved the effectiveness and robustness of the proposed algorithm with the adaption for non-superfluous images.

Keywords: Edge detection, feature extraction, fire & flame images

I Introduction

The characteristics of flame & fire are usually based on luminous nature. Characteristics & the distributive aspect is visible via the frequency of flickering that depicts the geometrical measurements. These measurements are important for various technologies to monitor the propagation of combustion flames with effect from the present quality of fossil fuel, biomass & has been leading to a poor quality, instability of flames due to combustion & high pollutant emissions in power generation plants[1].

The techniques for visualizing the characteristics of different flames of power generation industry & laboratory research is emphasized using the prior electrical or optical sensing, ionization based detection & thermocouple based detection to quantify the various parameters such as shape, size, stability etc [10]. Flames are justified via the rapid variations over time being an important indication to the existence of flames. With the volatility of flames, measured by its oscillating frequency > 0.5 of contours, chrominance & luminosity values [8], it becomes an essential aspect to focus for the determination of the nature of fire/flame through its proper edge detection.

A number of methods have been reported for the detection of the flame edges prior by trying to represent in Fourier domain which does not carry any time information to be computed [8]. A flame edge detection has been performed using Hidden Markov Models [7] using a multifunctional instrumentation system for monitoring the characterization of combustion flames [2] & also by methods of subtracting the current image from the background & detection by threshold [11]. Edge detection has also been achieved by using the conventional methods of Sobel, Roberts, Lapliance, Prewitt, & Canny but the results are rather unclear with discontinued edges & additional artifacts embedded in the outputs.

II Related Work

Edge detection is analyzed by using the mathematical representation of first order & second order derivatives. The first order finds the gradient & second order gives the magnitude of the edge. A flame region has a stronger luminance in comparison to its ambient background and the boundary between the flame region and its background is mostly continuous. The strategy used is to detect the coarse and the superfluous edges in a flame image, if there is only one main flame and if the image contains multiple flames, it is segmented as to contain one flame. Identify the flame's primary edge and remove irrelevant ones to project the continuous edge.

The common edge-detection methods like Sobel, Prewitt, Roberts, Canny and Laplacian method 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. Figure 1(a)–(f) shows examples of results obtained by the conventional edge-detection methods along with the original image.

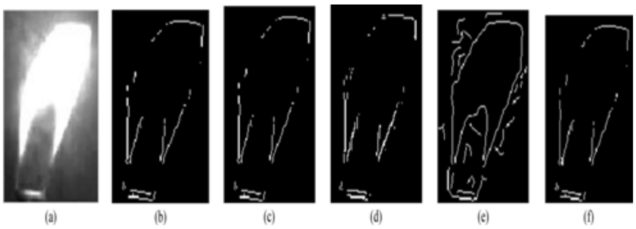

Figure 1. Representative results using the common edge-detection methods and Laplacian method. (a) Original image. (b) Sobel method. (c) Prewitt method. (d)Roberts method. (e) Canny method. (f) Laplacian method.

The expected flame edge should be one and only one clear, continuous, and uninterrupted edge. However, as the results have shown, the edges identified using these methods are often disconnected and fragmented [Figure 1(b)–(f)]; some of the methods can only identify a part of the flame edge [Figure 1(b)–(d)] or wrongly identify small edges that are obviously not the edges of the main flame [Figure 1(e)]. The results have therefore suggested that it is not always possible to obtain ideal edges from real-life images of moderate complexity, thus complicating the subsequent task of interpreting the image data.

Some research works related to flame and fire edge detection were reported for different applications; however, the methods do not emphasize the continuity and clarity of the flame and fire edges. It is therefore desirable to develop a dedicated edge detection method for flame and fire image processing. Accordingly, Tian Qiu et. al, developed new computing algorithm [1] to process a combustion image and to identify flame/fire edges.

The algorithm has been split into following logical steps:

Step 1 – Adjusting the grey level of a flame image.

As the image has a wide distributed scale of the grey levels, an initial adjustment is required to redistribute using a histogram to equalize the grey levels to be spread entirely over the given image normalized in the range [0,1]. Using the probability of the occurrence of a pixel of gray level I in the image is

$$P_x(i) = p(x = i) = \frac{n_i}{n}, 0 < i < L$$

L – Total number of grey levels in the image.

n – Total number of pixels in the image.

n_i – Total number of pixels with grey level i.

The Cumulative distribution function CDF is used for redistribution and equalization given by

$$CDF_x(i) = \sum_{j=0}^{i} p_x(j)$$

Step 2 – Smoothening the image to eliminate noise.

The image considered with variation in the grayscale represented as noise is filtered using the standard convolution methods by application of a suitable mask. A Gaussian mask is selected to minimize the localization edges to preserve the edges for further detection.

$\frac{1}{115}$

2	4	5	4	2
4	9	12	9	4
5	12	15	12	5
4	9	12	9	4
2	4	5	4	2

Step 3 – Using the Sobel operator for finding the basic edges

The Sobel operator is applied to the image to detect the preliminary edges by performing a spatial gradient over the image that reveals the distinct pixels by their gray scale varied from its neighboring pixels. The strength & the direction of the edges pixels are retrieved from this gradient & magnitude respectively. The Sobel operators applied horizontally and vertically to find the gradient in the x and y direction respectively are

-1 0 1   -1 -2 -1

$M_x =$ -2 0 2 $M_y =$ 0 0 0

-1 0 1 1 2 1

Step 4 – Adjusting Thresholds for better results.

The two thresholds are used to classify the pixel to belong to the edge if the magnitude of the gradient is higher than T_H or if there is a path to another pixel which is above T_L. All the other pixels not at the peak of the gradient are suppressed to highlight the edge. A preliminary edge image (PEI) is formed by detecting all the pixels foreseen to belong to the edge represented with discontinuous contour. These are further eliminated by interpolation through which the gaps between the contours existing as part of the background pixels are highlighted and connected using the 4 neighborhoods.

Step 5 – Removing unrelated edges in the PEI.

The PEI acquired from the previous image is traced by forming blocks of matrices with varying sizes to eliminate those pixels that are not a part of the edge revealed. For every pixel belonging to the edge, it is verified to have either one or more neighboring points or a conjunction of points based on which it is deduced to be either an isolated point or an end point or a normal transition point. All those points that have not been deducted are eliminated from the PEI.

Step 6 – Achieving a clearly defined edge.

The Euclidean distance measure D is computed for the starting and ending point of the contour defined from the previous process to evaluate the curve representing the edge of the flame is closed else LMS computation process is applied to derive an adjusted T_H. The Euclidean Distance D is computed between the C_s (S_x, S_y) & $C_e(E_x, E_y)$ as

$$D = \sqrt{(E_x - S_x)^2 + (E_y - S_y)^2}$$

III Proposed Work

As the algorithm discussed in the previous section of this paper, works for superfluous flames & unable to detect the edges of fire/flame images with either low luminosity or low intensity, the proposed work corrects the basic image by considering the individual components of any image - luminance, intensity & color.

The intensity factor is adjusted to lie between low & high thresholds for the entire image provided by a color correction function. As the pixels that are below certain low levels of intensity are increased, this might provide an adverse effect of glaring to objects contained in the image.

Hence a color correction is performed once again considering only the color component of the objects changed to restore their prior levels.

Algorithm:

1. Read input Image, low_limit, high_limit
2. I = double(Image)
3. Consider the luminance(Y), Intensity(I) & color(Q) components independently;
4. For every row of the Input Image
   - Sort these elements into ascending order of its values;

     vmin(k) = low_limit;

     vmax(k) = high_limit;

     where k= 1,2,3 represent luminance, Intensity color components;
   - If (Color component)

     convert rgb to ntsc values for min & max ;

     else if (black & white)

     min & max remain the same;
   - Assign the vmin & vmax to the entire image & give the output image

The above algorithm is repeated to restore the glared up object's intensity values to its original levels to distinguish them from the background via their contours.

IV Results and Discussions

After implementing the algorithm as described in Section III, many of flame images were processed using this algorithm so as to evaluate its effectiveness. Most of the flame images were taken for propane Bunsen flames burning in open air. Some of the images were attained from the Internet with courtesy of permission of use.

Figure 2 illustrates the results (b & d) of images with (a) and without (c) noise using existing approach.

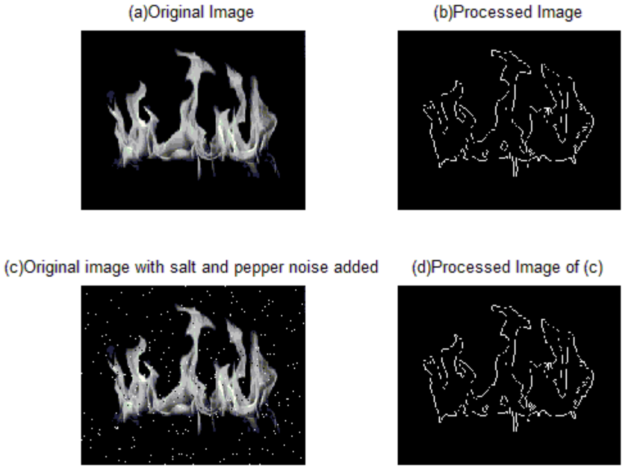

Figure 2

Figure 3 shows the input image after color correction with high limit 10.

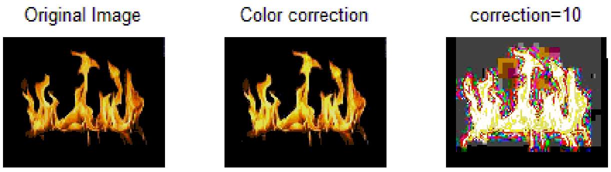

Figure 3

Figure 4 shows how our approach used to give more cleared result (b & d) for the same image with (a) and without (c) noise.

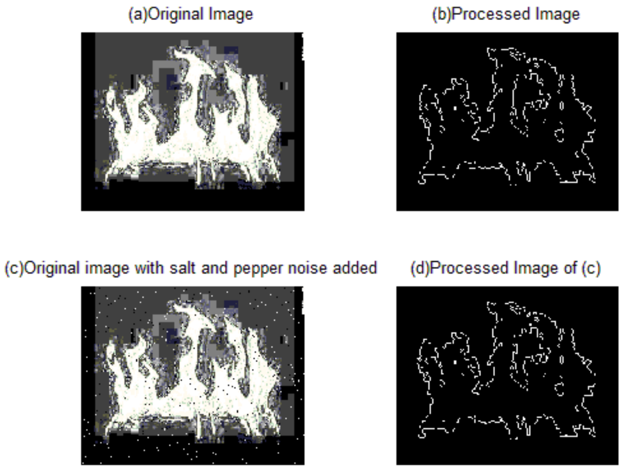

Figure 4

Figure 5 shows how existing approach not producing the result for low intensity based images.

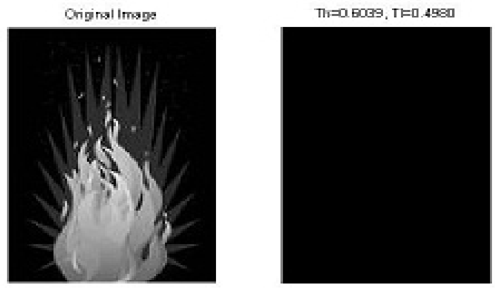

Figure 5

Figure 6 shows how existing approach not producing the result for low intensity based images.

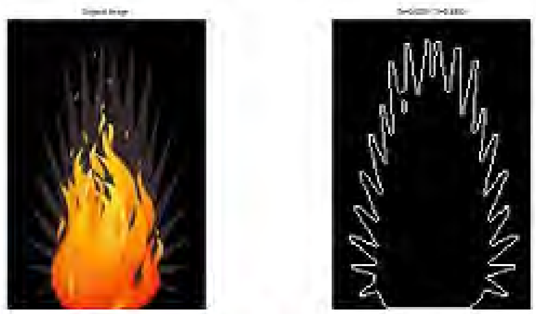

Figure 6

Similarly the Figure 7 and 8 shows typical processed flame images with edges identified.

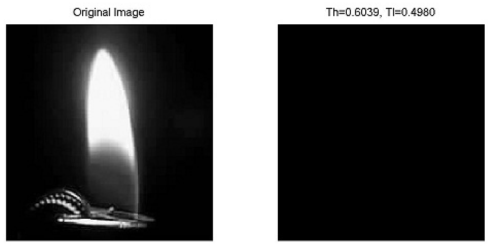

Figure 7

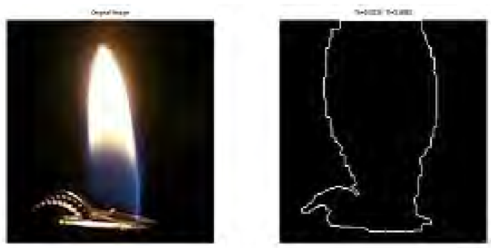

Figure 8

In comparison with the test results shown in Figure 1, it can be clearly observed that the developed algorithm can successfully detect clear edges of the flame and disregard unrelated artifacts, which common edge-detection methods cannot achieve. The proposed method makes it much easier to distinguish the flame region from the background.

V Conclusion

After the flame characteristics are analyzed, a new flame edge-detection method has been developed and evaluated in comparison with conventional methods. As per the existing algorithm for detection of fire & flame edges giving a clear & continuous edges when compared to the other traditional methods that has been envisaged for processing & analysis of fire & flames captured in laboratories with the prime feature of auto-adaptive nature for various scenarios.

The existing algorithm as specified, works only for the superfluous flames with high intensity & contrast depicted with the results given. Hence our algorithm overcomes this constraint by identification of clear & continuous edges of any fire/flame images for processing in its respective identified area as also been depicted by the results. Hence the work presented aims to detect the flame/fire & to identify its contours with respect to any clarity of the images.

VI References

[1] Tian Qiu, Yong Yan, and Gang Lu, "An Auto adaptive Edge-Detection Algorithm for Flame and Fire Image Processing", IEEE Transactions on Instrumentation and Measurement, Vol. 61, No. 5, May 2012.

[2] Qiu T, Y. Yan, and G. Lu, "A new edge detection algorithm for flame image processing," in Proc. IEEE I2MTC, Hangzhou, China, May 10–12, 2011, pp. 281–284.

[3] Lu G., Y. Yan, and M. Colechin, "A digital imaging based multi-functional flame monitoring system," IEEE Trans. Instrum. Meas., vol. 53, no. 4, pp. 1152–1158, Aug. 2004.

[4] D. S. Huang, L. Heutte, and M. Loog, "Real-time fire detection using camera sequence image in tunnel environment," in Proc. ICIC, vol. 4681, LNCS, 2007, pp. 1209–1220.

[5] Z. Zhang, J. Zhao, D. Zhang, C. Qu, Y. Ke, and B. Cai, "Contour based forest fire detection using FFT and wavelet," in Proc. Int. Conf. CSSE, Wuhan, China, Dec. 12–14, 2008, pp. 760–763.

[6] X. Zhou, F. Yu, Y. Wen, Z. Lu, and G. Song, "Early fire detection based on flame contours in video," Inf. Technol. J., vol. 9, no. 5, pp. 899–908, 2010.

[7] B. U. Toreyin, Y. Dedeoglu, and A. E. Cetin, "Flame detection in video using hidden Markov models," in Proc. IEEE ICIP, Sep. 11–14, 2005, p. II-1230-3.

[8] B. U. Toreyin, Y. Dedeoglu, U. Gudukbay, and A. E. Cetin, "Computer vision based method for real-time fire and flame detection," Pattern Recognit. Lett., vol. 27, no. 1, pp. 49–58, Jan. 1, 2006.

[9] M. I. Chacon-Murguia and F. J. Perez-Vargas, "Thermal video analysis for fire detection using shape regularity and intensity saturation features," in Proc. MCPR, vol. 6718, Lecture Notes in Computer Science, 2011, pp. 118–126.

[10] S. M. Razmi, N. Saad, and V. S. Asirvadam, "Vision-based flame analysis using motion and edge detection," in Proc. ICIAS, no. June 15–17, 2010, pp. 1–4.

[11] B. U. Toreyin and A. E. Cetin, "Online detection of fire in video," in Proc. IEEE Conf. CVPR, 2007, pp. 1–5.

[12] G. Lu, G. Gilabert, and Y. Yan, "Vision based monitoring and characterization of combustion flames," J. Phys. Conf. Ser., vol. 15, no. 15, pp. 194–200, 2005.

[13] H. C. Bheemul, G. Lu, and Y. Yan, "Three-dimensional visualization and quantitative characterization of gaseous flames," Meas. Sci. Technol., vol. 13, no. 10, pp. 1643–1650, Oct. 2002.

[14] Q. Jiang and Q. Wang, "Large space fire image processing of improving canny edge detector based on adaptive smoothing," in Proc. Int. CICCITOE, 2010, pp. 264–267.

[15] C. W. Adkins, "Users guide for fire image analysis system-Version 5.0: A Tool for measuring fire behavior characteristics," U.S. Dept. Agric. Forest Service, Southern Res. Station, Asheville, NC, Gen. Tech. Rep. SE93, 1995.

[16] X. She and F. Huang, "Flame edge detection based on C–V active contour model," in Proc. Int. Conf. Artif. Intell. Comput. Intell., 2009, vol. 2, pp. 413–417.

[17] R. C. Gonzalez and R. E. Woods, Digital Image Processing, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, 2002.

[18] J. Canny, "A computational approach to edge detection," IEEE Trans. Pattern Anal. Mach. Intell., vol. PAMI-8, no. 6, pp. 679–698, Nov. 1986.

[19] K. R. Castleman, Digital Image Processing. Englewood Cliffs, NJ: Prentice-Hall, 1995.

[20] SWRI, Small-scale liquid pool fire characterization. [Online]. Available: http://www.swri.org/4org/d01/fire/firetech/about.htm

[21] D. Ziou and S. Tabbone, "Edge detection techniques: An overview," International Journal of Pattern Recognition and Image Analysis, vol. 8, no. 4, pp. 537–559, 1998.

[22] W. S. Steven, The Scientist and Engineer's Guide to Digital Signal Processing. San Diego, CA: California Tech. Publ., 2003.

[23] Qiu T, Y. Yan, and G. Lu, "A medical axis extraction algorithm for combustion flames through digital image processing," Proc. 6th ICIG, Hefei, China, Aug. 12–15, 2011, pp. 182–186.

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