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# Flame Monitoring Using Auto-Adaptive Edge Detection

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**Abstract:** Edge detection and segmentation are widely used in image processing applications. Edges are significant local changes of intensity in an image. It is difficult to detect the coarse and superfluous edges in a fire and flame image. This study proposes 2 edge, the edge detected to be continuous and long enough. The detection algorithms called auto-adaptive edge detection and fuzzy logic which is used to find the longer edges in the fire and flame images. This auto-adaptive mechanism and fuzzy logic are trying to guarantee edges detected by the proposed methods are consecutive rather than short line segments. In this study, shows the effectiveness of the 2 edge, detection algorithms and gives the comparative results. Finally, it detects the nature of the flame.

**Key words:** Edge detection, auto-adaptive edge detection, fuzzy logic, proposed methods, flame

## INTRODUCTION

In fire and flame image processing, edge detection is the important technique. It lays a foundation for several upcoming processing. Flame monitoring is important in fossil-fuel-fired combustion systems, especially in power generation plants. There are several reasons to identify the flame edges. First, the flame edges are used to find the flame characteristic parameters such as size, shape, stability and location. Second, the flame edges can reduce the amount of data processing and it also removes the unwanted information such as background noise in the image. In other words, edge detection can preserve the structural properties of the flame and meanwhile shorten the processing time. Third, edge detection can be used to separate a group of flames. This is helpful for multiple monitoring of flames in the industrial furnaces where a multiburner system is used.

Edges typically occur on the boundary between 2 different regions in an image. Various physical events cause intensity changes such as geometric events and non geometric events. Several issues in the fire and flame image are it is highly sensitive to noise and the detected edges are not continuous and it lacks clarity. It is difficult to detect the coarse and superfluous edges in a fire and flame image. There are several classical edge detection techniques such as roberts, prewitt, sobel and canny. By using these techniques the longer edges are not accurately detected.

To overcome these issues gaussian filter is used to remove the noise in the fire and flame images and the proposed algorithm called auto-adaptive edge detection and fuzzy logic are used to find the longer edges in the fire and flame images. This autoadaptive mechanism is trying to guarantee the edge detected to be continuous and long enough. The fuzzy uses if-then rules and have simple structures to implement edge detection algorithm. The edge detected by the proposed methods are consecutive rather than short line segments. These algorithms detect the coarse and superfluous edges in a fire and flame image. Finally, it detects the nature of the flame.

In this study, several conventional edge-detection methods have been examined to assess their effectiveness in flame edge identification and gives the comparative results. Finally, it detects the nature of the flame.

## RELATED RESEARCH

Several approaches have been proposed in literature for edge detection in fire and flame image processing. Razmi *et al.* (2010) have proposed the algorithms for flame detection using video processing. The flame detection algorithm are used to detect the flame using motion and shape features can be accomplished by using background subtraction and edge detection approach. In motion detection, the flames are identified by the movement of the flame. For the edge detection method, the colour pixels are used to detect the shape of flame. The combined action of motion detection and edge detection to proposed a flame detection system. She and Huang (2009) have proposed a method based on C-V active contour model for detection the edges of the boiler furnace flame image in power plant. Using this model continuous edges are detected. This is good for sequential flame image monitoring in power plant.

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Toreyin *et al*. (2005) have proposed a new method called hidden markov model which is used to detect the flames in video. It detects the flame based on both motion and colour clues. This model also detects the flicker of the flame. Jiang and Wang (2010) have developed a new method to avoid the huge damage caused by fire. Adaptive canny edge algorithm and flame geometric features are combined to inspect the flame area. This proposed approach was more robust to noise and used to segment the consecutive frames flame area.

Choy *et al*. (2011) have proposed new model called multiphase image segmentation based on fuzzy region competition and spatial and frequency information. The association degree of each pixel in an image regions are measured using fuzzy membership function. The spatial and frequency region information are measured by the term data fidelity. It is more efficient for identifying the synthetic textures, natural textures and real-world natural images. Celik *et al*. (2007) have proposed 2 models based on luminance and on the chrominance. For the luminance model, concepts from fuzzy logic are used in luminance model and made the classification more effectively in fire, flame and fire like colored objects. The differences between fire and non fire pixels are achieved by chrominance model. The fire pixel classification can be made combining the mask derived from fuzzy logic with the chrominance model.

Ham *et al*. (2010) have proposed a flame detection algorithm using FFA which is based on probabilistic membership functions. The FFA combines with fuzzy logic it produces continuous detection of fire and flame images. It is more robust to fast expanding fire and flames with dynamic colors and gives better performance. Ko *et al*. (2011) have proposed a fire-flame detection method using Fuzzy Finite Automata (FFA). The shape of fire flames continuously changes with respect to time so that the variables in FFA are time-dependent and irregular. The FFA is based on the analysis of fire patterns and probability density functions. It achieve more robust for similar cases, such as shadows, rapid changes in color and motion when compared to other methods.

## CONVENTIONAL EDGE DETECTION METHODS

There are several conventional edge detection methods in fire and flame image processing. They are:

- Prewitt edge detection
- Roberts edge detection
- Sobel edge detection
- Canny edge detection

**Sobel edge detection:** The sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically, it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. The sobel operator is slower but its larger convolution kernel smooths the input image to a greater extent and so makes the operator less sensitive to noise. The operator also generally produces considerably higher output values for similar edges, compared with the roberts cross.

**Roberts edge detection:** It performs a simple, quick to compute, 2-D spatial gradient measurement on an image. This method emphasizes regions of high spatial frequency which often correspond to edges. The input to the operator is a grayscale image, as is the output. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. As with the roberts cross operator, output values from the operator can easily overflow the maximum allowed pixel value for image types that only support smaller integer pixel values (e.g., 8-bit integer images). When this happens the standard practice is to simply set overflowing output pixels to the maximum allowed value. The problem can be avoided by using an image type that supports pixel values with a larger range.

**Prewitt edge detection:** The Prewitt takes the central difference of the neighboring pixels. This method is very sensitive to noise. It is also called as compass operators because it has the ability to determine the gradient direction. The compass masks are obtained by taking one mask and rotating it to the eight major directions, such as North, Northwest, West, Southwest, South, Southeast, East and Northeast. Each of the resulting kernels is sensitive to an edge orientation ranging from 0-315°C in steps of 45°C, where 0°C corresponds to a vertical edge.

Even though, different gradient edge detection requires large time consuming calculation to estimate the direction from the magnitudes in the x- and y-directions, the compass edge detection obtains the direction directly from the kernel with the highest response. It is limited to 8 possible directions however knowledge shows that most direct direction estimates are not much more perfect. This gradient based edge detector is estimated in the 3×3 neighborhood for eight directions.

**Canny edge detection:** The Canny operator was designed to be an optimal edge detector it takes as input a gray scale image and produces as output an image showing the positions of tracked intensity discontinuities. The Canny operator research in a multi-stage process. First convolve the image with the gaussian filter. Compute the gradient of the resultant smooth image and store the edge magnitude and edge orientation separately in 2 arrays.

The next step is to thin the edges. This is done using a process called non-maximal suppression. Examining every edge point orientation is a computationally intensive task. To avoid such intense computations, the gradient direction is reduced to four sectors. The range of 0-360° is divided into 8 equal portions. About 2 equal portions are designated as one sector. Therefore, there will be 4 sectors. The gradient direction of the edge point is first approximated to one of these sectors. After the sector is finalized, assume a point M (x, y). The edge magnitudes M ($x_1$, $y_1$) and M ($x_2$, $y_2$) of 2 neighbouring pixel s that falls on the same gradient direction. If the magnitude of the point M (x, y) is less than the magnitude of the points ($x_1$, $y_1$) or ($x_2$, $y_2$), then the value is suppressed that is the value is set to zero otherwise the value is retained.

Apply the hysteresis thresholding. The idea behind hysteresis thresholding is that only a large amount of change in the gradient magnitude in edge detection and small changes do not affect the quality of edge detection. This method uses 2 thresholds: $T_0$ and $T_1$. If the gradient magnitude is greater than the value $T_1$, it is considered as a definite edge point and is accepted. Similarly, if the gradient magnitude is less than $T_0$, it is considered as a weak edge point and removed. However, if the edge gradient is between $T_0$ and $T_1$, it is considered as either weak or strong based on the context. This is implemented by creating 2 images using 2 thresholds $T_0$ and $T_1$.

Low threshold creates a situation where noisier edge points are accepted. On the other hand, a high value of the threshold removes many potential edge points. So, this process first thresholds the image with low and high thresholds to create 2 separate images. The image containing the high threshold image will contain edges but gaps will be present. So, the image created using the low threshold is consulted and its 8 neighbors are examined. So, the gaps of the high threshold image are bridged using the edge points of the low threshold image. This process thus, ensures that the edges are linked properly to generate the perfect contour of the image.

## AUTO-ADAPTIVE EDGE DETECTION

Auto-adaptive edge detection is used to detect the longer edges by using canny algorithm. Canny uses multi stage algorithm to detect a wide range of edges in images. It gives good localization and response. Then better detection, especially in noise condition. Figure 1 shows the flowchart of auto-adaptive edge detection.

For generating the edge map first select any point from the detected edges using canny algorithm. Then find the neighbors for that particular point. If neighbor number is equal to zero then isolate and remove this point. If neighbor number is equal to one then find the one end point. If neighbor number greater than one then move till neighbor number is equal to one and find another end point. Connect all end points to find the longer edges.

Using auto-adaptive technique the nature of the flame detected. The threshold calculation is used to detect that given flame is normal or abnormal. The threshold values lies between 0 and 1. The threshold calculation is done by using initial threshold value and pixel value. If pixel value is less than threshold value then the values are assigned as $M_1$. If the pixel value is greater than threshold value then the values are assigned as $M_2$. Calculate the new threshold value by using $T_{new} = (M_1+M_2)/2$. If the value of $T_{new}$ gets varied then repeat these steps again and again until the value become constant.

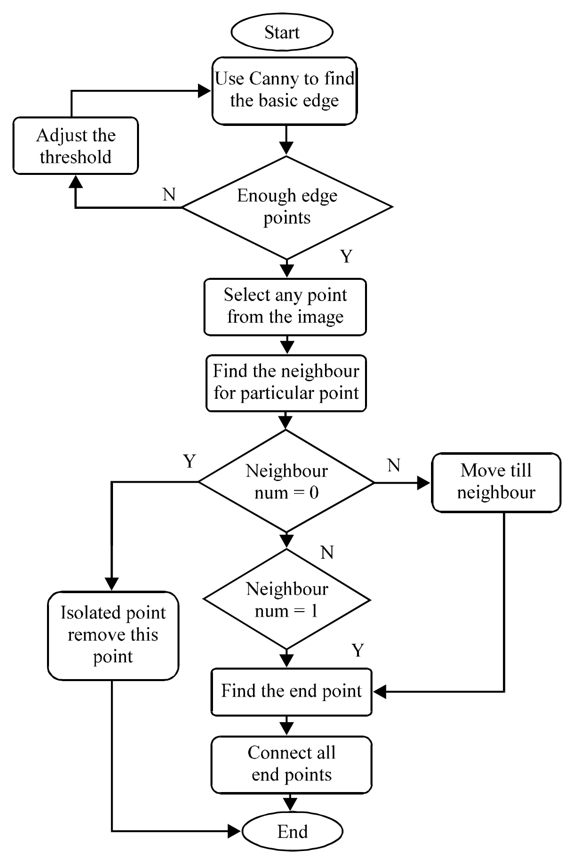


Fig. 1: Flowchart of auto-adaptive edge detection

## FUZZY LOGIC TECHNIQUE

Fuzzy logic has been applied to many fields including fire and flame image processing. The fire and flame edges are detected by using the fuzzy logic technique.

Fuzzy logic is a form of many-valued logic or probabilistic logic. It deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets (where variables may take on true or false values) fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Then the linguistic variables are also used. Figure 2 represents the fuzzy processing.

Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. It results more accurate representations of the way systems behave in the real world. The benefits of fuzzy logic include its simplicity anditsflexibility. Fuzzy logic can handle problems with imprecise and incomplete data and

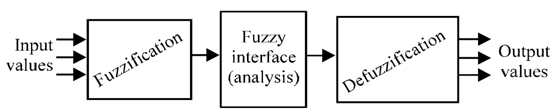


Fig. 2: Fuzzy processing

it can model nonlinear functions of arbitrary complexity. If you do not have a good plant model or if the system is changing, then fuzzy will produce a better solution than conventional control techniques.

Fuzzy logic model is also called fuzzy inference systems consist of a number of conditional if-then rules. For the designer who understands the system, these rules are easy to write and as many rules as necessary can be supplied to describe the system adequately.

## EXPERIMENTAL SETUP

In this study, experimental results are made to verify the accuracy of the edge detection methods. The result analysis for different types of conventional edge detection methods namely roberts, prewitt, sobel, canny and the proposed method called auto adaptive edge detection are shown in Fig. 3.

The conventional edge detection methods namely roberts, prewitt, sobel and canny is shown in terms of a comparitive in Fig. 3. The X-axis represents edge detection methods. The Y-axis represents accuracy of edge detection.

Figure 3 explains that canny edge detection method having high accuracy of 0.51, compared to other edge detection methods. The sobel edge detection method shows medium accuracy of 0.39 which is comparitively lesser than canny edge detection but greater than robert

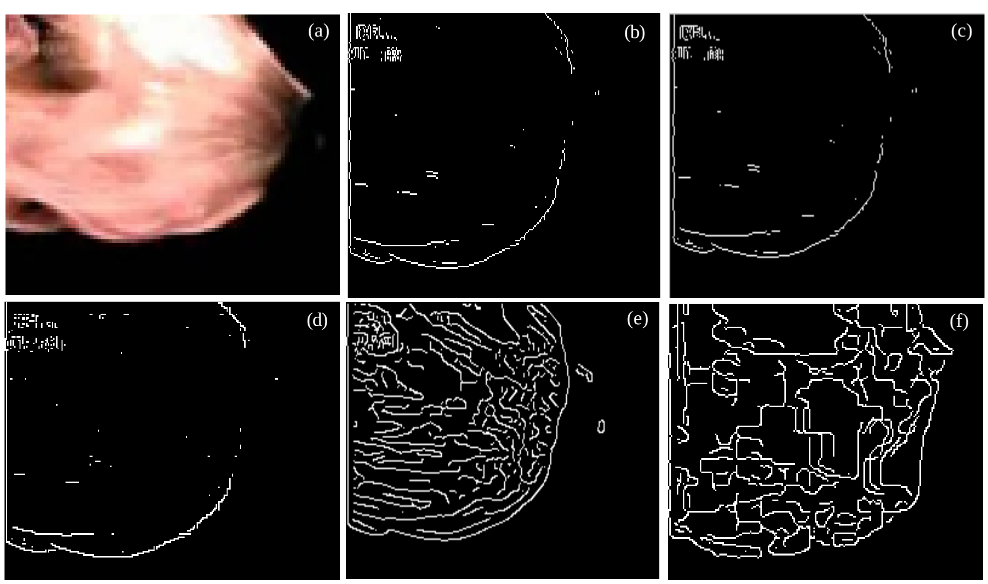


Fig. 3: Several conventional edge detection methods and the proposed algorithm: a) Original image; b) Sobel edge detectio; c) Prewitt edge detection; d) Robert edge detection; e) Canny edge detection; f) Auto adaptive edge detection

Table 1: Edge detection with accuracy

| Edge detection methods with their representation | Accuracy | (X and Y-axis) | Accuracy level |
|---|---|---|---|
| Robert edge detection (3) | 0.01 | 3, 0.01 | Very low |
| Prewitt edge detection (2) | 0.10 | 2, 0.1 | Low |
| Sobel edge detection (1) | 0.39 | 1, 0.39 | Medium |
| Canny edge detection (0) | 0.51 | 0, 0.51 | High |

and prewitt edge detection methods. The reason for sobel's medium accuracy is because of the variating x and y values. The accuracy falls to the lowest for robert and prewitt edge detection methods where the values are shows medium accuracy of 0.39 which is comparitively lesser than canny edge detection but greater than robert and prewitt edge detection methods. The reason for sobel's medium accuracy is because of the variating x and y values. The accuracy falls to the lowest for robert and prewitt edge detection methods where the values are determined to be 0.01 and 0.1. These lowest accuracy points are plotted against X and Y bar graph as shown where the performance is comparitively low with respect to the other edge detection methods. Table 1 shows the edge detection methods with accuracy. The ranges provide details of accuracy for the edge detection methods used.

## CONCLUSION

In this study, researchers proposed a new flame edge-detection method called autoadaptive edge detection has been developed and evaluated in comparison with conventional methods. This algorithm 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.

## RECOMENDETIONS

The future work of this study is to detect the edges using fuzzy logic and gives the comparative results for both auto adaptive edge detection and fuzzy logic technique.

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