An Edge Detection Algorithm for Flame and Fire Alert System

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Abstract: ***This algorithm is used for the detection of flame and fire in fire alert systems. The algorithm uses Canny's edge detection with Gaussian filter for detecting the edges of the flame/fire. 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, edge analysis, image processing, monitoring, shape measurement, Gaussian filter

1. Introduction

To meet the stringent standards on combustion efficiency and pollutant emissions, quantitative flame monitoring is becoming increasingly important in fossil-fuel-fired combustion systems, particularly in power generation plants. This has led to a wave of research on advanced flame imaging technologies both in the power generation industry and in laboratory research. In fire safety engineering, flame image processing is also emphasized as image-based flame detectors are increasingly applied in fire detection systems. Compared to conventional flame detectors such as those based on optical sensing, ionization current detection, and thermocouple, image-based flame detectors are deemed more appropriate in fire detection because of their capability for remote detection of a small-sized fire, as well as having other advantages.

As one of the important steps in flame and fire image processing, edge detection is often the precursor and lays a foundation for other processing. There are several reasons why it is necessary to identify flame edges. First, the flame edges form a basis for the quantitative determination of a range of flame characteristic parameters such as shape, size, location, and stability. Second, the definition of flame edges can reduce the amount of data processing and filter out unwanted information such as background noise within the image.

A number of methods have been reported for identifying flame edges for the geometric characterization of a flame or fire. Adkins developed a software tool to analyze fire images, with which one can use a mouse to trace the flame edge. It is a manual edge-detection method, but it does show the importance and usefulness of the flame/fire edge detection. Measurement Bheemul et al. introduced an effective method to extract flame contours by detecting the changes of the brightness in the horizontal direction line by line over a flame image, but the method is only suitable for simple and steady flames. Zhang presented a new method using FFT and wavelet transform for the contour analysis of forest fire images on a video. Lu proposed an algorithm for early fire detection and tested it on video clips. Toreyin et al. succeeded in detecting the fire in a real-time video using different methods such as hidden Markov models and wavelet transform. Chacon-Murguia and Perez-Vargas managed to detect and analyze fire information on a video through the analysis of shape regularity and intensity saturation feature. Razmi et al. used a background subtraction and Prewitt edge-detection approach to detecting flames for fire protection systems. She and Huang proposed a Chan–Vese active contour model for the edge detection of flames in a power plant. Jiang and Wang also demonstrated an improved Canny edge detector which was used to detect moving fire regions in large space fire images. Although each of these methods has its own advantages for the given tasks, such as fire detection or shape reconstruction in a complex background, or helping to detect an early fire and trigger a fire alarm, they have some limitations. For instance, some flame edges detected are unclear, discontinuous, or do not well match the actual flame shape. For the purpose of detecting the flame's size and shape and consequently, the geometric characteristics, it is necessary to attain the clear, continuous and, where possible, closed edge of the flame.

2. Existing System

A typical edge in an image might, for instance, be the border between blocks of different colors or different gray levels. Mathematically, the edges are represented by first - and second-order derivatives. The first order derivative (i.e., gradient) of The edge-detection methods that have been published maybe grouped into two categories according to the computation of image gradients, i.e., the first order or second-order derivatives. In the first category, edges are detected through computing.

3. Proposed Method

In general, 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. Furthermore, in most cases, there is only a main flame in the image; otherwise, the image can be segmented so that each segmented area contains only one main flame. Accordingly, a computing algorithm is proposed where these features are used to identify flame edges. The basic strategy is to detect the coarse and superfluous edges in a flame image then identify the flames principal edges and remove irrelevant ones. The algorithm can be divided into the following logical steps.

Step 1) Adjusting 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 ni 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 [21] ni (4)Px (i) = p(x = i) =, 0 < i < Ln

where L is the total number of gray levels in the image, n the total number of pixels in the image, and px (i) the histogram for pixels with i, normalize to [0, 1].

Step2) 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.

Step 3) Canny with Gaussian Edge Detection

The essential idea in detecting step edges is to find points in the sampled image that have locally large gradient magnitudes. Much of the research work in step edge detection is devoted to finding numerical approximations to the gradient that are suitable for use with real images. The step edges in real images are not perfectly sharp since the edges are smoothed by the low-pass filtering inherent in the optics of the camera lens and the bandwidth limitations in the camera electronics.

The images are also severely corrupted by noise from the camera and unwanted detail in the scene. An approximation to the image gradient must be able to satisfy two conflicting requirements:

(1) The approximation must suppress the effects of noise, and (2) the approximation must locate the edge as accurately as possible. There is a trade-off between noise suppression and localization. An edge detection operator can reduce noise by smoothing the image, but this will add uncertainty to the location of the edge; or the operator can have greater sensitivity to the presence of edges, but this will increase the sensitivity of the operator to noise.

The type of linear operator that provides the best compromise between noise immunity and localization, 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 in Section 5.1. 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.

Step 4) Adjusting 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.

4. Conclusion

After the flame characteristics are analyzed, a new flame edge-detection method has been developed and 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 [27], such as 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.

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Author Profile

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