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دانشگاه صنعتی مالک اشتر

دانشگاه جامع علمی - کاربردی

A New Algorithm for Edge Detection based on Edge Following

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ABSTRACT

Edge detection belongs to the category of image segmentation techniques which extracts edges/lines within the image. Generally speaking, an edge consists of the boundary pixels which connect two separate regions with different attributes such as gray levels, tristimulus values, or texture. Despite the large number of available researches, edge detection still remains a challenging endeavor in image processing for noise corruption and boundary uncertainty. In this paper, a new gradient-based framework is proposed for edge detection. In this paper, we proposed a new edge detection algorithm. First, the image is smoothed by a Gaussian filter for noise suppression. After computation of the image gradient, a non-maximum suppression algorithm is performed on the gradient amplitude to extract some edge seeds. Once the smoothed image is filtered by using the LoG filter, every seed point with no zero-crossing match in the resultant image is discarded. Finally, the edge map of the image is obtained by using an edge following algorithm.

This method has considerable potential dissociation between retail removed edges because it follows the edge of the algorithm. Experimental results show that the proposed method performs better detection and removal dissociation between edges than all these operators under almost all scenarios.

Keywords: Edge detection, Edge following, Gradient, Laplace, Hysteresis thresholding.

1. INTRODUCTION

Generally, edge is defined as the boundary pixels in the image which connect two separate regions with different image attributes such as luminance or tristimulus values [1]. Isolating objects from the background is the most advantageous ability of the edge detection algorithms which was frequently used in image segmentation, boundary feature extraction, and object description.

Although edge detection is a traditional research field in image processing, it still remains a challenging endeavor because of edges uncertainty, noise corruption, and non-uniform intensity variations, especially in the images with complicated background. Thus, many researchers attempted to tackle this problem until now. For example, Basu [2] compared different linear and nonlinear Gaussian-based edge detection methods. Although nonlinear operators provided significant improvement in edge-detection and edge-localization over linear operators such as Marr-Hildreth, Hermite and Canny operators, they suffer from computational burden, convergence difficulties, and multiscale uncertainties. Thus, to obtain the best performance, providing a compromise between strengths and weak-points of Gaussian-based edge detection operators is necessary.

Shrivakshan and Chandrasekar [3] presented fundamental concepts of various Gradient-based and Laplacian-based edge detector filters. It was shown that Canny edge detector provides better performance compared to a number of edge detection operators under almost all scenarios [4-6]. Thus, Canny operator is a challenging counterpart for every edge detection algorithm.
In recent years, researchers attempted to develop improved edge detection algorithms by using the combination of frequently-used well-known traditional methods. For example, Ashour and El-Sayed [7] proposed a new edge detection algorithm based on the Shannon entropy and multi threshold values given by histogram analysis. However, threshold-based edge detectors usually provide weak performance against the noise.

In another work, Zaart [8] employed the 2-D gamma distribution for edge detection. Despite promising results, it suffers from heavy computational burden, because of using a large number of processing masks. Somkansa [9] took advantage of both the intensity and texture features for edge detection in medical images which are usually corrupted by noise. In more detail, after smoothing the image, an edge map was extracted based on textural features and Canny edge detector. Finally, candidate edges within the image are extracted by using an edge following algorithm which employs the amplitude and direction of the smoothed image gradient. Although this method provided suitable results for noisy images, it may neglect weak edges and merge neighboring edges.

Gudmundsson *et al.* [10] utilized genetic algorithms for edge detection in order to avoid problems arising from the large search space. A number of researchers used artificial neural networks for edge detection [11-13]. Generally speaking, non-linear edge detectors such as those developed based on fuzzy logic, neural networks, and genetic algorithm provided better performance compared to linear filtering-based methods [2].

Chen and Chen [14] proposed an elegant edge-detection method based on an edge following algorithm. In more detail, they initially indicate some seed points in the gradient amplitude image by using a histogram analysis algorithm. Then, the neighboring edge pixels are added to the set of seed points based on the direction of the gradient vector. Kang and Wang [15] proposed an edge detection algorithm based on maximizing an objective function. Finally, a number of researchers took advantage of active contours for contour extraction [16, 18, 19]. Each active contour moves a curve in the image by minimizing the internal and external energy functions in the light of Euler-Lagrange theorem.

In this paper a new edge detection algorithm is proposed. We primarily choose some edge seeds from the image and then, the edge map is obtained by using an edge following algorithm. In more detail, the image is initially smoothed by a Gaussian filter for noise suppression. After computation of the gradient of the smoothed image, all local maxima of the gradient amplitude in the image domain are specified by using a non-maximum suppression algorithm in order to collect a number of edge seeds. Then, once the smoothed image is filtered by the LoG filter, every edge seed which does not indicate a zero-crossing in the filtered image is discarded. Finally, the edge map of the image is given by a new edge following algorithm.

This paper is organized as follows. Section II proposes a new method of edge detecting with a detailed description of each step. Section III displays our edge detection results compared with the results of Canny and LoG methods. Finally we present conclusions in Section IV.

2. MATERIALS AND METHODS

As illustrated in Fig. 1, the proposed method consists of four steps including preprocessing, non-maximum suppression, LoG filtering, and edge following which will be briefly stated in the sequel.

2.1 Preprocessing

In the preprocessing step, the image is primarily smoothed by the Gaussian filter for noise suppression:

$$s(\mathbf{x}) = f(\mathbf{x}) * g_\sigma(\mathbf{x}) \tag{1}$$

where $f(\mathbf{x})$ is the gray-level image given for edge detection and g_σ indicates the Gaussian filter with standard deviation of σ. Although this parameter needs to be adjusted according to the amount of noise present in the image, weak edges may be disappeared by using a too large value for σ. Then, the gradient of $s(\mathbf{x})$ is computed by using Sobel filters as follows:

$$\nabla s(\mathbf{x}) = \frac{\partial s(\mathbf{x})}{\partial \mathbf{x}} = \left(\frac{\partial s(\mathbf{x})}{\partial x}, \frac{\partial s(\mathbf{x})}{\partial y}\right) \tag{2}$$

Obviously, the gradient vector can be specified by using the phase direction, $p(\mathbf{x})$ and amplitude, $q(\mathbf{x})$, terms:

$$\begin{cases} q(\mathbf{x}) = \sqrt{\left(\dfrac{\partial s(\mathbf{x})}{\partial x}\right)^2 + \left(\dfrac{\partial s(\mathbf{x})}{\partial y}\right)^2} \\ p(\mathbf{x}) = \tan^{-1}\left(\dfrac{\partial s(\mathbf{x})/\partial x}{\partial s(\mathbf{x})/\partial y}\right) \end{cases} \tag{3}$$

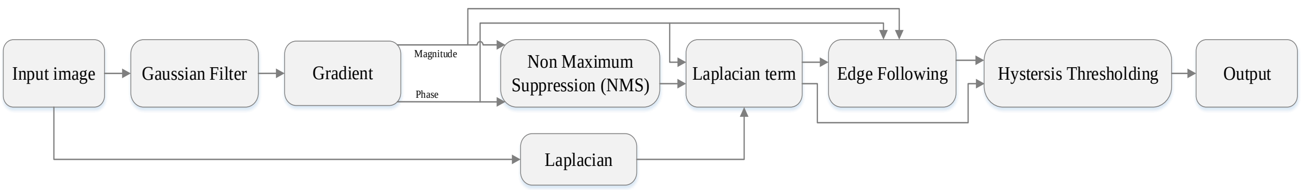


Fig. 1. *Block Diagram of proposed method.*

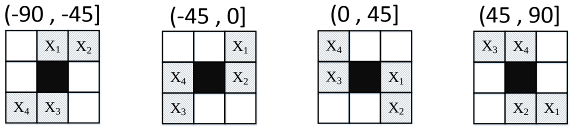


Fig. 2. *Neighborhoods corresponding to each gradient phase range.*

2.2 Non-maximum suppression

The main idea of NMS stands on this fact that every edge pixel is a local maximum of the gradient amplitude along the gradient vector. Thus, a pixel will belong to an image edge, if its gradient amplitude is larger than those of the neighboring pixels along the gradient vector. Each neighborhood has two pairs of pixels (Fig. 2).

Although every edge in the gradient amplitude image appears as a thick inflation, the real edge passes only through the crest. In the conventional edge detection algorithms, the non-maximum suppression (NMS) algorithm is used for thinning the edge inflation into the thickness of one pixel. After that, they specifies the candidate edge pixels by thresholding. In more detail, we used two threshold values based on mean and variance of amplitude.

$$\begin{cases} T_{up} = mean2(q(x)) + 2 * std2(q(x)) \\ T_{dn} = \dfrac{T_{up}}{2} \end{cases} \tag{4}$$

On the other hand, the image Laplacian has a zero crossing at the edge position. If Laplacian zero crossing occurs in a position, according to the gradient amplitude along the gradient vector, that pixel is on edge. As it is discussed in experimental results, Laplacian zero crossing term is effective and removes many noisy edge pixels. We select edge candidate pixels by combining Laplacian zero crossing property and non-maximum suppression method.

2.3 Edge Following

In order to find initial edge candidate points, soft threshold is employed, thus edges are discrete. Selecting a lower threshold for gradient magnitudes is a solution to this problem. It is obvious that an optimum threshold in all conditions does not exist. Another approach is using edge following.

In edge following method, at first, using edge particle image and morphological operations, the points with only one neighbor are selected; then a parameter (for example CTR) that indicates the maximum acceptable distance between two edge particles is defined. Then according to the direction of gradient vector, for each point, pairs of neighbors are selected (Fig. 2). Then the pairs of pixels with higher gradient magnitude, which do not include edge particles, will be selected as the next points for edge following process. In the edge following, if the following of an edge reaches to an edge particle in a smaller distance from CTR, all of the traversed pixels will be considered as edge, otherwise these pixels are not part of the edge.

2.4 Post Processing

The final step of the proposed algorithm is Hysteresis thresholding on the edge of the image. Based on Hysteresis thresholding method [21] the following three conditions must be satisfied:

The hysteresis mode uses a hysteresis loop to provide a more connected result. Any pixel above the upper threshold is turned white. The surrounded pixels are then searched recursively. If the values are greater than the lower threshold, they are also turned white. The result is that there are many fewer specks of white in the resulting image. This leads to the creation of 3 classes: below low threshold (to be removed), above high threshold (to be retained) and between low and high thresholds (to be retained only if connected to an edge above high threshold).

- If the gradient of a pixel is more than the hard threshold, then the pixel is definitely part of the edge.
- If the gradient of a pixel is less permissive than the threshold, it is not owned by any edge.
- For pixels whose gradients are more stringent than the threshold and the lower threshold is permissive, the edge is only defined when a continuous path between the pixels of the first group exists.

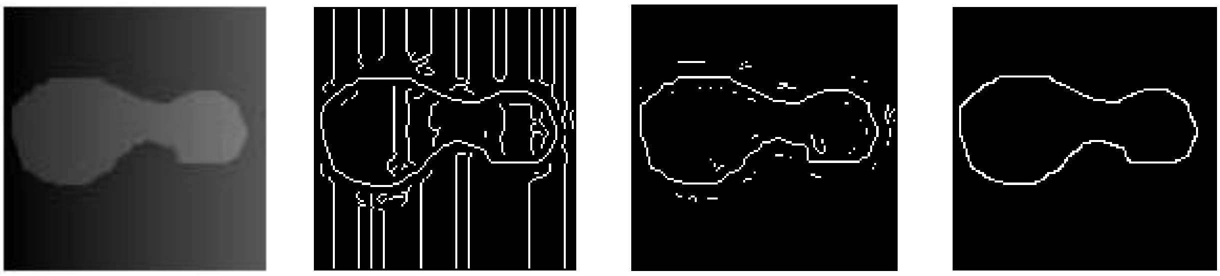
Since the gradient of all of the extracted edges in the last step is more permissive than the soft threshold, to apply hysteresis thresholding, only the places which definitely belong to the edge are selected. Then the connected edges to these points will be selected.

3. RESULTS AND DISCUSSIONS

The proposed algorithm is tested on 70 standard images and is compared to the previous classic methods such as LOG and Sobel. Analysis shows that the effect of the proposed method is better than those methods in Edge-preserving and noise elimination. Fig. 3-10 shows edge detection result of the proposed method in comparison with some edge finders.

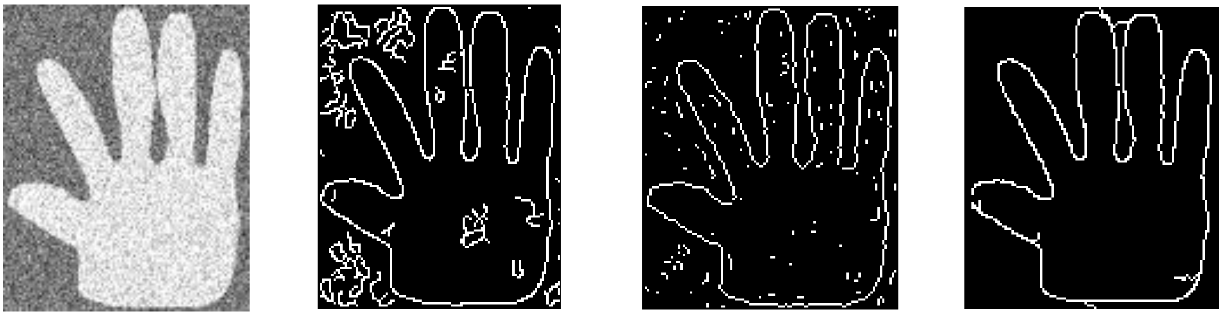
(a) (b) (c) (d)

Fig. 3. *(a) Original image, edge detection by (b) Canny, (c) LoG and (d) proposed method.*



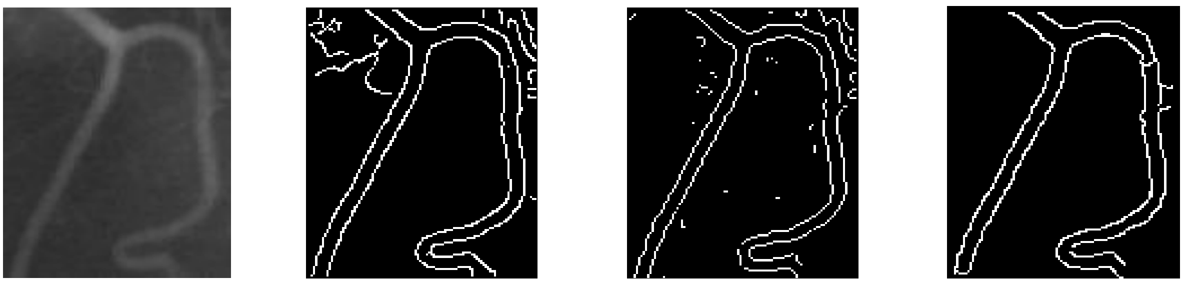
(a) (b) (c) (d)

Fig. 4. *(a) Original image, edge detection by (b) Canny, (c) LoG and (d) proposed method.*



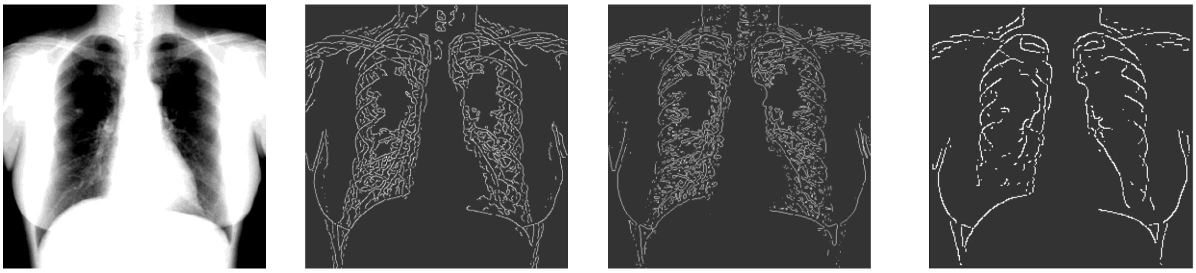
(a) (b) (c) (d)

Fig. 5. *(a) Noisy image, edge detection by (b) Canny, (c) LoG and (d) proposed method.*



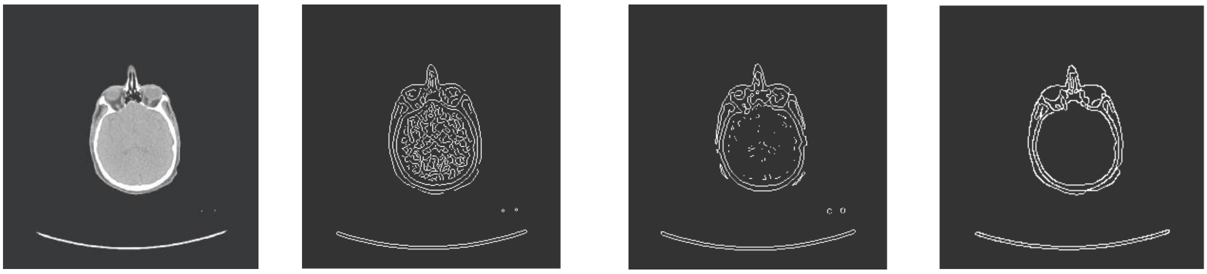
(a) (b) (c) (d)

Fig. 6. *(a) Original image, edge detection by (b) Canny, (c) LoG and (d) proposed method.*



(a) (b) (c) (d)

Fig. 7. *(a) Original image, edge detection by (b) Canny, (c) LoG, (d) proposed method.*



(a) (b) (c) (d)

Fig. 8. *(a) Original image, edge detection by (b) Canny, (c) LoG, (d) proposed method.*

(a) (b) (c) (d)

Fig. 9. *(a) Original image, edge detection by (b) Canny, (c) LoG, (d) proposed method.*

(a) (b) (c) (d)

Fig. 10. *(a) Original image, edge detection by (b) Canny, (c) LoG, (d) proposed method.*

4. CONCLUSION

Based on the Gradient and Laplacian, this paper has provided a novel method to detect the edge. The proposed method not only measures the normal images edges but also detects edges of the noisy images. First, the image is smoothed by a Gaussian filter for noise suppression. After computation of the image gradient, a non-maximum suppression algorithm is performed on the gradient amplitude to extract some edge seeds. Once the smoothed image is filtered by using the LoG filter, every seed point with no zero-crossing match in the resultant image is discarded. Finally, the edge map of the image is obtained by using an edge following algorithm. Results show that the proposed method have better performance in compared with similar methods, like Canny and LoG.

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