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Research and Implementation of an Improved Canny Edge Detection Algorithm

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Abstract. Edge detection is one of the most important steps in image processing and pattern recognition; it is also a critical technology of hand bone identification. Canny edge detection algorithm is simple, easy to implement and fast execution advantage, therefore, it still maintains a certain degree of competitiveness in the practical application. The principles and the existing problems of Canny algorithm are studied in this paper, against threshold problem, improved method of an adaptive threshold is proposed using Otsu method selected threshold, the split results would be better. The experimental results show that the proposed method can effectively extract the edge of the images.

Introduction

The mage-based applications are currently being used in a large variety of scientific fields such as aerospace, biology, medical sciences, geology, astronomy, robotics, remote sensing. Edge detection is one of the most important steps in image processing, analysis and pattern recognition systems. Conceptually, the most commonly proposed schemes for edge detection include four operations: smoothing, enhancement, detection and localization [1].

The Canny edge detector is a very popular and effective edge feature detector that is used as a pre-processing step in many computer vision algorithms. It is a multistep detector which performs smoothing and filtering, non-max suppression, followed by a connected-component analysis stage to detect “true” edges, while suppressing “false” non edge filter responses [2]. Canny suggested that the optimal edge detector maximizes the product of signal-to-noise and localization. He also found it necessary to constrain the smoothness of the edge detector. The resulting constrained optimal filter was similar to a derivative of a Gaussian [3].

Unfortunately, it is still sensitive to noise, and due to use the dual-threshold method connect edge, easily lead to discontinuous edges [4]. Need to select the appropriate parameters of the Gaussian filter in practice, template size and the appropriate threshold, to achieve effectively removal of noise at the same time to obtain a more accurate detection result. This paper presents an adaptive method to determine the level of the threshold.

Canny Edge Detection Algorithm

The Canny algorithm uses an optimal edge detector based on a set of criteria which include finding the most edges by minimizing the error rate, marking edges as closely as possible to the actual edges to maximize localization and marking edges only once when a single edge exists for minimal response [5]. According to Canny, the optimal filter that meets all three criteria above can be efficiently approximated using the first derivative of a Gaussian function, such as Eq. 1 and Eq. 2 [6].

The first stage involves smoothing the image by convolving with a Gaussian filter. This is followed that finding the gradient of the image by feeding the smoothed image through a convolution operation with the derivative of the Gaussian in both the vertical and horizontal directions. The 2-D convolution operation is described in the Eq. 3.

$$G(x,y)=\frac{1}{2\pi\pi^2}e^{-(x^2+y^2)/2\sigma^2} \quad (1)$$

$$\frac{\partial G(x,y)}{\partial x}\propto xe^{-(x^2+y^2)/2\sigma^2} \qquad \frac{\partial G(x,y)}{\partial y}\propto ye^{-(x^2+y^2)/2\sigma^2} \quad (2)$$

$$\Gamma(x,y)=g(k,l)\otimes I(x,y)=\sum_{k=-N}^{N}\sum_{l=-N}^{N}g(k,l)I(x-k,y-l) \quad (3)$$

Where: g(k,l)= convolution kernel; I(x,y) = original image; Γ(x,y) = filtered image; 2N+1 = size of convolution kernel. Both the Gaussian mask and its derivative are separable, allowing the 2-D convolution operation to be simplified. The non-maximal suppression stage finds the local maximum in the direction of the gradient, and suppresses all others, minimizing false edges. The local maximum is found by comparing the pixel with its neighbors along the direction of the gradient.

This helps to maintain the single pixel thin edges before the final threshold stage. Instead of using a single static threshold value for the entire image, the Canny algorithm introduced hysteresis threshold, which has some adaptivity to the local content of the image. There are two threshold levels, th , high and tl, low where th>tl. Pixel values above the th value are immediately classified as edges. By tracing the edge contour, neighboring pixels with gradient magnitude values less than th can still be marked as edges as long as they are above tl. This process alleviates problems associated with edge discontinuities by identifying strong edges, and preserving the relevant weak edges, in addition to maintaining some level of noise suppression. While the results are desirable, the hysteresis stage slows the overall algorithm down considerably.

Canny algorithm detected edge's effect is quite ideal. But, it is still sensitive to noise, and due to use the dual-threshold method to connect edge, easily leading to discontinuous edges. Need to select the appropriate parameters of the Gaussian filter in practice, template size and the appropriate threshold, to achieve effectively removal of noise at the same time to obtain a more accurate detection result.

Adaptive Canny Edge Detection Algorithm

The traditional Canny operator is based on optimization algorithm of the edge detection operator, has better anti-noise performance and detection accuracy. However, there is passive in its parameters and hysteresis threshold selection, mainly in the smoothing parameter δ of the Gaussian filter, high and low threshold needs to be determined artificially. Contradiction with the edge of the positioning capability, the smaller δ is, the more accurate the positioning is, but the image smoothing weakens, and noise influence increases; otherwise denoising is good and positioning offsets. Therefore, the filter smoothing parameter δ is often determined according to the practical applications in multiple measurements in experiments. The method has the advantage of using both high and low threshold is more flexible than using a threshold value, but there are common problems of threshold. High and low threshold inappropriate value, there will be a pseudo-edge or edge intermittent problem.

For the difficulty of traditional Canny operator to determine the dual-threshold, many domestic and foreign scholars propose some solutions. Used the following two: based on the principle of maximum entropy adaptive threshold selecting, the basic idea of the maximum entropy method is the use of the image gray distribution density function defined image information entropy; based on the Otsu adaptive threshold selection method. It is the judgment on the basis of the analysis and the method of least squares principle, using category variance as a criterion, selecting the interclass variance of gray value as the best threshold, applying to the NMS image is to calculate the maximum interclass variance $\eta = \sigma_B^2/\sigma_T^2$, which can get relatively satisfied test results.

This paper presents an adaptive method to determine the level of the threshold, the algorithm idea is as follows: the gradient histogram described is an edge strength information, which accounts for a small part of the edge information in an image, describing an image edge strength gradient histogram is different from gradation of the original image histogram. Gradient histogram has no apparent doublet, only in the image non-edge portion of a high peak, reflecting the image non-edge area

occupies substantially; the original corresponding to the edge region in the gradient histogram is approximately uniformly decreasing the distribution state, so the edge and non-edge region do not have obvious bottom boundaries. Therefore, using the Otsu method in gradient histogram, deviation of selecting the threshold will be larger. Image after non-maxima suppression, background area accounts for most proportion in the image would appear a spike; meanwhile, edge position in the gradient magnitude histogram of image will approximate to form a peak. At that time, using Otsu method selected threshold, the split results would be better.

Thereby, located after the image non-maxima suppression nonzero total pixels is N, the range of gradient values [1, L-1], the gradient i correspond to the number of pixels of Ni, its probability is Eq. 4.

$$P_i = \frac{N_i}{N} \quad (4)$$

Background class by the gradient value between [1,T] pixel composed, the target class of gradient value between [T+1,L-1] pixel composed. Background and objectives of the gradient mean values expressed as Eq. 5 and Eq. 6.

$$u_b(T) = \frac{\sum_{i=1}^{T} i \times P_i}{w_b(T)} \quad (5)$$

$$u_o(T) = \frac{\sum_{i=T+1}^{L-1} i \times P_i}{w_O(T)} \quad (6)$$

In which: $w_b(T) = \sum_{i=1}^{T} P_i$; $w_o(T) = \sum_{i=T+1}^{L-1} P_i$; $w_b(T) + w_o(T) = 1$.

Total image mean gradient defined as Eq. 7.

$$u = u_b(T)w_b(T) + u_o(T)w_o(T) \quad (7)$$

Interclass variance of two types defined as Eq. 8.

$$\delta^2(T) = w_b(T)[u_b(T) - u]^2 + w_o(T)[u_o(T) - u]^2 \quad (8)$$

In Otsu algorithm, in range [1, L-1] time value, so that maximum value T of the function value above is the optimal threshold value of the Otsu algorithm.

Experiments and Results Analysis

Experimental platform for matlab 2007, VC++ 2008. The Canny algorithm smoothing parameter δ = 0.4 in experiment. Images used are grayscale images of 8 bits size, the experimental results of the image shown in Fig. 1, Fig. 2 and Fig. 3.

In all the three figures, (a) shows the original image, (b) shows edge detection results of application of a traditional Canny algorithm, the parameters are the default values in the matlab 2007, (c)shows the results obtained by an adaptive algorithm in this paper. By comparison, in the second group of images, due to select the default setting parameters, the images appear the fracture, more false edges and other issues, thereby can be obtained conclusion that using consistent parameter is unscientific for different image, it will affect the detection results, particularly in the X-ray pictures. The hand bone X-ray picture belongs to grayscale, the brightness of the image is lower, grayscale is more concentrated and smaller difference, adaptive edge detection algorithm is more suitable for application. Therefore adaptive Canny edge detection algorithm can effectively detect the edges of the original image. Compared to the traditional Canny edge detection algorithm, adaptive threshold extent is improved, the artificially introduced error is reduced, more edge detail is detected in the target area, overall outline of the images is better, the same time some of the false edge is removed.

(a) Original Image (b) Canny Algorithm (c) Daptive Canny Algorithm

Fig. 1 Lena detection results of the three methods

(a) Original Image (b) Canny Algorithm (c) Daptive Canny Algorithm

Fig. 2 Peppers detection results of the three methods

(a) Original Image (b) Canny Algorithm (c) Daptive Canny Algorithm

Fig. 3 Hand bone X-ray detection results of the three methods

Conclusion

An adaptive Canny edge detection algorithm is proposed, which improves self - adaptive ability of threshold and can effectively detect the edges of the original image. The results show that proposed algorithm has lower artificial errors and more edge detail, overall outline of the images is better, in the same time, some of the false edges are removed.

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