

Image Edge Detection Algorithm Based on Fuzzy Logic*

Jian Zhao¹

¹Changchun Institute of Optics, Fine Mechanics and Physics, The Chinese Academy of Sciences, Changchun 130033, China
E-mail:zhaojian6789@126.com

Abstract - Since primary information of the target mainly concentrate in the edges, the edge detection of gray-scale image is very crucial in image processing and Target recognitions. Detecting the edges of images accurately and precisely is quite challengeable. Therefore, an improved edge detecting algorithm based on fuzzy logic is proposed, which has adapted new subject degree and enhance factor. Experiment results on video images have successfully proved this method to have better detection effects.

Index Terms - Fuzzy Logic, Edge Detection.

1. Introduction

Video image target tracking is one of the main areas of real-time processing of the image. The edges of the target image contain a lot of effective information. As a result, the local image generally displays discontinuities in gray feature with fluctuating gray values which change smoothly along the edges but vary dramatically along the normal direction of the edges.

The edge is usually divided into two categories: the step-shaped and the roof-shaped. As for the step-shaped edges, there are significant gray scale value differences between the two side edges of the image. As for the roof-shaped edges, they are located at the borders where the gray scale value gradually increases and decreases. In mathematical field, derivatives of the gray value are often used to describe the variations of gray scale. The first derivative reaches its maximum at the edges for the step-shaped edges. As for the roof-shaped edges, the second derivative reaches its minimum at the edges while the first derivative equals to zero.

Edge detection is the most fundamental skills in image processing and computer vision. Collecting information from the edges of images accurately and timely has significant impact on the quality of subsequence image processing. There are a variety of algorithms used to detect the edge, including the classic Roberts operator, Sobel operator, Laplacian operator, canny operator, and etc[1]. As mathematical theories and artificial intelligence develops, brand new methods begin to emerge, such as the wavelet transform edge detection method based on mathematical morphology[2], fuzzy theory and neural network methods.

All methods have their advantages and disadvantages. Some of them have high precision but slow arithmetic speed while others may have relatively high arithmetic speed but low noise resistivity. Therefore, defects may occur while these various algorithms are used.

2. Fuzzy theory

LA. Zadeh introduced the fuzzy logic in 1965 along with his proposal of fuzzy set theory. The fuzzy logic investigates the “partial truth” phenomena widespread in the nature and information technology by using mathematical means, providing a powerful mathematical tool for information science. In recent years, fuzzy logic has been rapidly developing and has a wide range of applications in the fields of automatic control, information processing, artificial intelligence, pattern recognition, and etc.

In nature, a lot of vague concept and description are used, such as “fast”, “dark” and etc. The fuzzy logic investigates how to describe and analyze concepts by using mathematical means. The fuzzy set is a collection of propositions which does not have a clear boundary. In a normal set, any element can either belong to set or not belong to the set. However, for the fuzzy sets, an element can be both in and out of the set or even can have a truth degree—the extent of in and out. In order to describe this property, the concept of the degree of membership (i.e. the truth degree) is used, which have a range of [0, 1].

If x is an element which belongs to set A , then the fuzzy set A according to Zadeh’s method would be,

$$A = \frac{u_A(x_1)}{x_1} + \dots + \frac{u_A(x_n)}{x_n} = \sum_{i=1}^n \frac{u_A(x_i)}{x_i} \quad (1)$$

where the domain of set A is U , the degree of membership of x is $u_A(x)$

The primary task of fuzzy processing is to determine the membership function by using statistics. The membership function $u_A(x)$ shows the lim ratio between the frequency of x under condition A and the total interrogation frequency n . Then,

$$u_A(x) = \lim_{n \rightarrow \infty} \frac{\text{frequency of } x \in A}{n} \quad (2)$$

Where the characterization of a degree of membership $\in [0,1]$ proofread your paper. Do not add page numbers.

3. Image Edge Detection Based on Fuzzy Logic

A. Pal-King edge detection algorithm

Pal and King firstly apply the fuzzy logic theory to the image edge detection and therefore propose the image fuzzy

* This work is supported by the program of academy-locality cooperation of the Chinese Academy of Sciences (2011CJT0004), the Jilin province science and technology development plan item (20090557 and 20125092).

edge detection algorithm (Pal algorithm). Here are the main steps of the Pal algorithm:

- 1) Map the image from spatial domain to fuzzy domain (i.e. a fuzzy matrix).
- 2) Define the membership function.
- 3) Enhance the image using non-linear function transformation in the fuzzy space.
- 4) Convert the enhanced image from the fuzzy domain to spatial domain using the inverse transformation.
- 5) Detect the edges.

The Pal algorithm is based on traditional algorithms in edge detection, it has the following drawbacks:

- 1) When the image is converted from grayscale space to fuzzy space, a complicated power function is used as the fuzzy membership function. Therefore it may create problems such as overloaded computations and time consuming.
- 2) The algorithm uses the "min" or "max" operator in the case of relatively weak contrast of the edge on both sides. As a result, the intensity of detected edge is relatively low as well, making it inconvenient for edge joint and feature extracting, etc.

B. Edge detection algorithm based on fuzzy logic

The instructions of the image edge detection algorithm based on fuzzy logic are as the followings:

Firstly, optimize the threshold using the Otsu method. The principle is to use category variance as a criterion, and then select the maximum gray value of the variance between different classes as the threshold [3] [4].

If a given image has an L-level of gray scale value with a threshold value of t , which divides the image into two parts: target (A) and background (B), then the probability of the occurrence of the target portion would be

$$\omega_A(t) = \sum_{i=0}^t p_i \quad (3)$$

where p_i stands for the probability of occurrence of gray level i . Similarly, the probability of the occurrence of the background would be,

$$\omega_B(t) = \sum_{i=t+1}^{L-1} p_i \quad (4)$$

And the mean value for the target portion and background portion would be,

$$u_A(t) = \sum_{i=0}^t ip_i / \omega_A \quad (5)$$

$$u_B(t) = \sum_{i=t+1}^{L-1} ip_i / \omega_B \quad (6)$$

Therefore the formula for the variance between two classes would be,

$$d(t) = \omega_A(t)\omega_B(t)(u_A(t) - u_B(t))^2 \quad (7)$$

Select the maximum variance value as the threshold T ,

$$T = \underset{0 < t < L}{\text{Arg Max}} d(t) \quad (8)$$

Secondly, re-define the membership function

$$u_{mn} = \begin{cases} \frac{x_{mn}}{X_T} & x_{mn} \leq X_T \\ \frac{X_{\max} - x_{mn}}{X_{\max} - X_T} & x_{mn} > X_T \end{cases} \quad (9)$$

where X_T is the threshold value T , x_{mn} is the element of the original image data

Process the images in the fuzzy domain. The purpose is to increase the gap between different gray levels. This can be achieved by both the attenuation processing for pixels with small changes in gray level and the enhancement processing for the ones with large changes. As a result, the contrast of gray level in the edge regions will be enhanced.

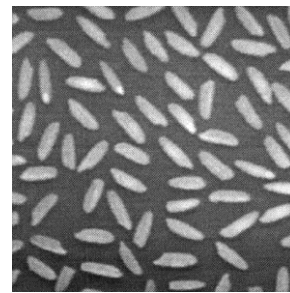
Finally, detect the edges using conventional algorithms. To get better results before the edge extracting operation, the use of a median filter or an averaging filter for smoothing is suggested.

4. Experimental results

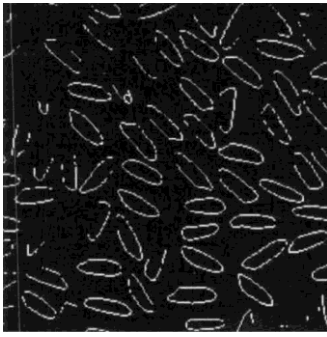
In order to validate the effectiveness of this algorithm, a comparison experiment between the proposed algorithm simulation test and the Sobel algorithm (of the images of rice and a cameraman) is carried out. Figure 1 shows the original image of rice, the processed image using the Sobel algorithm of rice and the edge detection image using the proposed algorithms. Figure 2 shows the original image of a cameraman, the processed image using the Sobel algorithm and the one using the proposed algorithms.

Based on results from the simulation tests, the proposed algorithms can extract more edge information than the Sobel algorithm, providing accurate and clear images. At the same time, the effects of line detection are better than the ones in processed images using the Sobel algorithm as well.

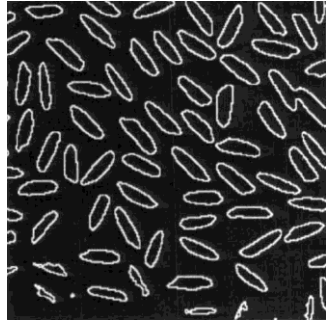
Fully understood the complexity of the proposed algorithms, an excess number of iterations of the algorithms may cause the increased likelihood of weak edge signal remaining undetected. Therefore, a relatively small number of iterations is suggested.



(a) the original image



(b) the result of Sobel algorithm



(c) the result of the proposed algorithm

Fig.1 the Rice Image



(a) the original image



(b) the result of Sobel algorithm



(c) the result of the proposed algorithm

Fig.2 the Cameraman Image

5. Conclusion

The proposed edge detection algorithm based on fuzzy logic defines a new membership function and enhanced operator, applying the fuzzy logic to the threshold value calculation and using different thresholds for different image features, and therefore improves edge detection

References

- [1] Ruiling Duan, Qingxiang Li, Yuhe Li, "Summary of Image Edge Detection", Optical Technique, vol.31, no.3, pp.415-419, 2005.
- [2] Qiangjin Zhang, Dan Yang, Xiaohong Zhang, Yongxin Ge, "Wavelet Edge Detection Method Based-on Multi-scale Fuzzy Logic", Journal of Chongqing University(National Science Edition), vol.28, no.10, pp.62-65, 2005.
- [3] Siqi Han, Lei Wang, "A Survey of Threshold Methods for Image Segmentation", Systems Engineering and Electronics, vol.24, no.6, pp.91-94, 2002.
- [4] KAPUR JN, SAHOO PK, WONG AKC, "A new method for grey-level Picture thresholding using the entropy of the histogram", Computer Vision, Graphics and Image Processing, vol.29, no.2, pp.273-285, 1985.