Edge Detection Based on Class Ratio

Chang-Huang Chen(陳長煌)

Department of Electrical Engineering
Tung-Nan Institute of Technology,
152, Sec.3, PeiShen Rd., Shenkeng, Taipei, 22202, Taiwan, R.O.C.
E-mail: chchen@www.tnit.edu.tw

ABSTRACT

This paper presents a new method for edge detection in digital image processing. Edge detection is based on the values of class ratio, a concept given in grey system theory. Since edges of an image correspond to intensity variation, according to the definition of class ratio, steeper edge results in larger class ratio while smoother intensity change result in small class ratio. To the aim of edge detection, the horizontal and vertical direction class ratios of the image are calculated, then a thresholding action is carried out to track the edges. Some experimental results obtained by this method are demonstrated and compared with Sobel edge detector.

Keywords: Edge detection, Class ratio, Image processing, grey system theory

1. Introduction

Computer vision is currently finding wide application in a large variety of fields such as aerospace, biology, medical science, geology, astronomy, engineering and etc. Since the increasing demands on production automation and quality control, industrial application of digital image processing system are also rapidly growing. Detection of edge in an image is a very important step toward complete image understanding. Since edges are important features of an image, there is a lot of significant information contained in edges of an image. Edges often correspond to object boundaries, shadow transition. It helps to extract useful features for pattern recognition.

Many algorithms for edge detection have been proposed. In general, edge detection can be classified in two categories: gradient operators and second derivative operators[1-9]. Due to an edge in an image corresponds to an intensity change abruptly or discontinuity, step edge contain large first derivatives and zero crossing of the second. In the case of first derivative operation, edge can be detected as local maximum of the image convolved with a first derivative operator. Prewitt, Robert, Sobel[8] and Canny[9] implement their algorithm using this idea. For the second derivative case, edges are detected as the location where the second derivative of the image crosses zero. The using of Laplacian of Gaussian convolution mask is the most common method of the second derivative operator. Fig.1 illustrate the aspects of differentiation operation. Fig.1a represents the intensity function of a 1D image. Fig.1b and Fig.1c are the first derivative and second derivative of Fig.1(a), respectively.

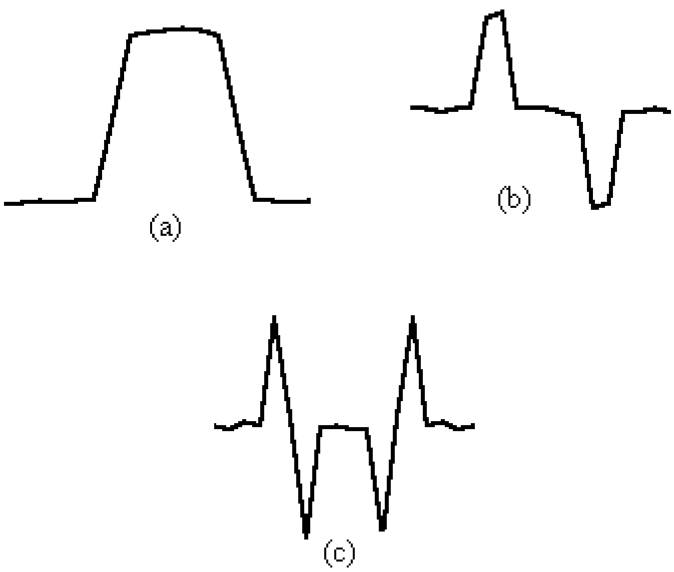


Fig. 1 The relationship of intensity function, first and second derivative of an image. (a)The intensity function, (b) and (c)are the first derivative and the second derivative of (a), respectively

However, it is well known that differentiation operation emphasize noise, especially high frequency noise. To overcome this difficulty, filtering is adopted in the edge detection algorithm. For example, R.C. Hardie and C.G. Boncelet apply a nonlinear edge enhancing prefilter to convert smooth edges to step edges and suppress noise[10], and F. Russo proposed fuzzy reasoning filter technique[11].

Some others edge detection approaches including: directional filtering[12] proposed by A. P. Paplinski, fast recursive shortest spanning tree[13] by S.H.Kwok and A.G.constantinides, observed luminance contrast by T. P. Kaushal[14], and etc. In the study presented here, a new method based on class ratio is proposed. It will demonstrate that the proposed method performs very well. Before addressing the method in detail, the definition for class ratio will be given first in next section.

2. Class Ratios as Edge Detector

In grey system theory, class ratio is used to check whether a series is feasible for GM(1,1) modeling[14,15]. It is also used for detection the jump points in a series, and hence for GM(1,1) modeling of jump trend series[16,17]. Here, it is adopted for detecting edges of an image. In this section, the definition of class ratio will be presented first. Then, the application of class ratio as an edge detector will be demonstrated.

For a given discrete series $x = \{x_0, x_1, x_2, \ldots, x_n\}$, where n+1 is the total number of data. The class ratio is then defined as:

$$\lambda_i = \frac{x_{i+1}}{x_i} \qquad (1)$$

for i = 0,1, 2,…,n. it is obviously that (a)$\lambda_i = 1$, for $x_{i+1} = x_i$, (b)$\lambda_i > 1$, for $x_{i+1} > x_i$, and (c)$\lambda_i < 1$, for $x_{i+1} < x_i$

Since an edge is the boundary between two regions with relatively distinct level properties, the class ratio of an edge point with respect to adjacent point will be change more abrupt than those the level variation are smoothly. This observation leads to the application of class ratio for edge detection. If we take the logarithm value of class ratio, denoted as α, i.e.

$$\alpha = \{ \alpha_i \mid i = 0,1,\ldots, n\}$$

where

$$\alpha_i = \log(\lambda_i) \qquad (2)$$

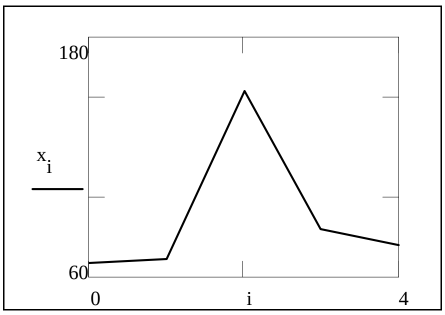
then, edge can be determined as zero crossing of α. For simplify, α will be called as LCR, logarithm of class ratio. For example, assume that $x = \{x_0, x_1, x_2, x_3, x_4\} = \{67, 70, 153, 86, 78\}$ be a portion of gray level value in horizontal direction of an image. It represents a 1-pixel width intensity variation, i.e. 1-pixel width edge, at x_2 position, as shown in Fig.2. Calculate the class ratio λ of x,

$$\lambda = \{1.045, 2.186, 0.562, 0.907\}$$

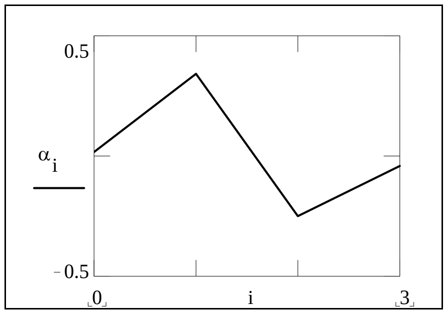
and the LCR,

$$\alpha = \{0.019, 0.34, -0.25, -0.042\}$$

It is obviously that a zero crossing exist between position x_1 and x_2, which corresponds to an edge with 1-pixel width.



(a)



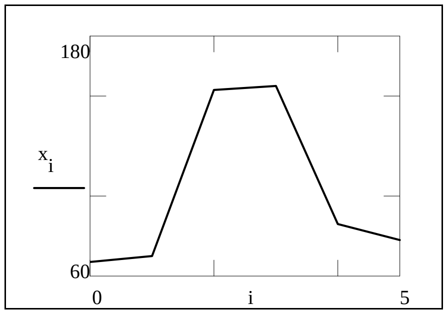
(b)

Fig.2: (a)1-pixel width edge of 1D image, and(b) its LCR

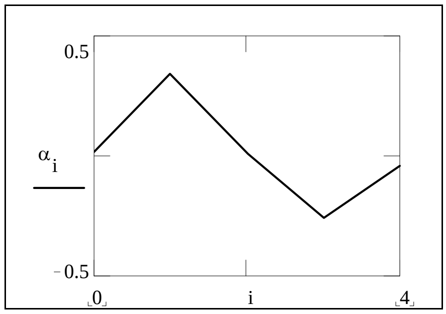
Now consider the situation of 2-pixel width edge. Let x = {67, 70, 153, 155, 86, 78} be the intensity values of a portion of a 1D image, refer to Fig.3. The LCR of x is:

$$\alpha = \{0.019, 0.34, 0.006, -0.256, -0.042\}$$

It is obviously that a zero crossing exists between $x_1$and x_3, since $\alpha_1 = 0.34$ and $\alpha_3 = -0.256$, which correspond to two edge points at x_2 and x_3. Edges with more than two pixel width can easily be obtained by extending the conclusion made in this subsection.



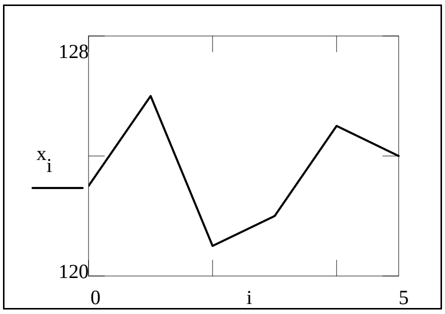
(a)



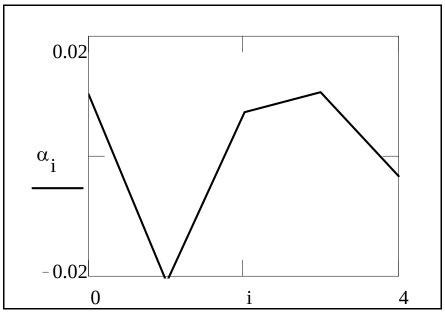
(b)

Fig.3 (a) 2-pixel width edge of 1D image, and (b) its LCR

Difficulty arises when two LCR with small value and opposite sign. In Fig.4(a), the 1D image have small intensity variations between 121 and 126, which results in the value of LCR falling into [-0.025, 0.02] as shown in Fig.4(b). Since the intensity values are very close to each other, no edges exist in this image, even though there are three zero crossings appeared in Fig.4(b). To overcome this problem, a thresholding operation is applied before determining the edges according to the original LCR values. That is, those $|\alpha_i| < \varepsilon$ are excluded for edge identification to ensure successful tracking correct edges.



(a)



(b)

Fig.4 Fiction edges occur when image with small variation of intensity. (a)Intensity value, and (b) its LCR

3. The proposed algorithm

Consider a 1D image, as introduce in previous section, the edge detector can be expressed as a mapping operation over the region of gray level, and be defined as:

$$E : f(x) \rightarrow g(\alpha) \tag{3}$$

where $f(x)$ is the intensity function of the original 1D image , x is the position of pixels of the image, and $g(\alpha)$ is a binary image generated by E operation. Furthermore, the function, $g(\alpha)$, is defined as:

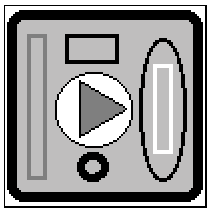
$$g(\alpha) = \begin{cases} 0, & |\alpha| < \varepsilon \\ 1, & |\alpha| \geq \varepsilon \end{cases} \tag{4}$$

where $\alpha_i = \log(f(x_{i+1})/f(x_i))$, logarithm of class ratio of intensity values of an image. Meanwhile, 0 and 1 are used to represent black and white pixels, respectively, i.e. a value of 0 means an edge point exists and a value of 1 corresponds to non-edge point. And ε is a small threshold value, which control the resolution of edges of the final image. Although the edge detector based on Equ.(3) and Equ.(4) workable to 1D images, it can easily extend to 2D images. In other words, the 2D image can be dissected into 1D image in row-wise and column-wise. Actually, in our implementation, edges in two directions, vertical and horizontal, are detected first in row-by-row and column-by-column fashion, respectively. Thereafter, these two edges are combined together to obtain the final result. In summary, the procedures of the proposed algorithm can be outlined as follow:

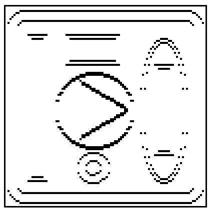
1. Calculate the horizontal and vertical logarithm of class ratio of an image
2. Detect the horizontal and vertical edge points using threshold operation
3. Combine horizontal and vertical edges by And-ing operator
4. Output the final result

4. Experiments results

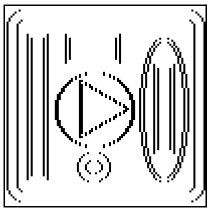
Experiment 1: Fig.5(a) shows a test image used in first example. The horizontal and vertical direction edges are shown in Fg.5(b) and Fig.5(c), respectively. The final result yields by the proposed algorithm is depicted in Fig.5(d). For comparison, the resulting image using Sobel operator generated by LabView with IAMQ vision, is also depicted in Fig.5(e). It is obvious that the proposed algorithm acquired better performance.



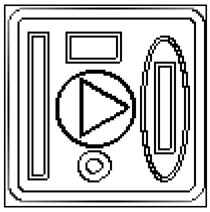
(a)



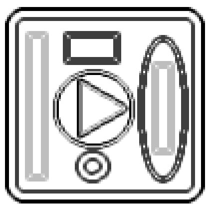
(b)



(c)



(d)

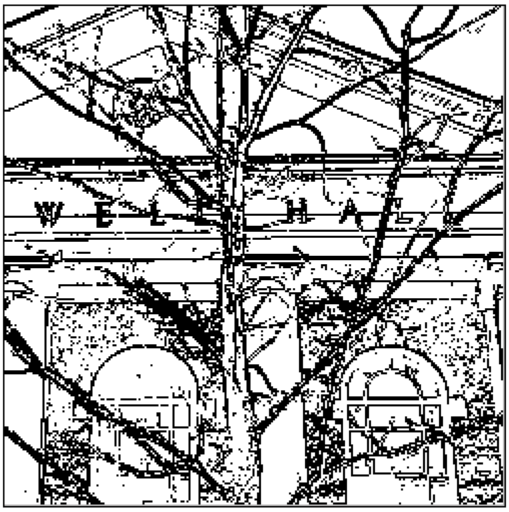


(e)

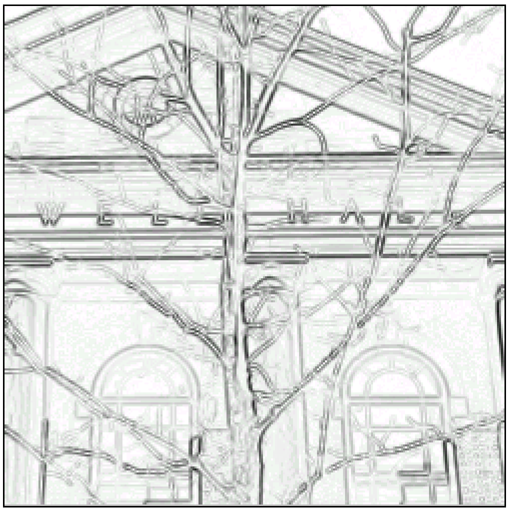
Fig.5 (a)test image, (b)horizontal direction edges, (c) vertical direction edges, (d) by the proposed algorithm, (e) Sobel operator

Experiment 2: A more complicated image, image of Well Hall, is given in Fig.6(a). The Final result obtained by the proposed algorithm is illustrated in Fig.6(b), while Fig.6(c), in inversion form for comparison, is the result generated using Sobel edge detector.

(a)



(b)

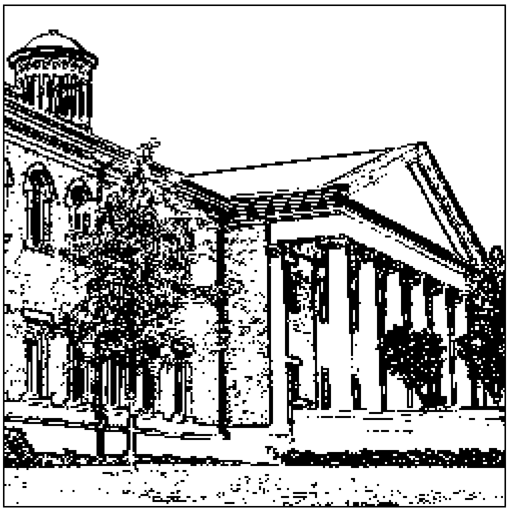


(c)

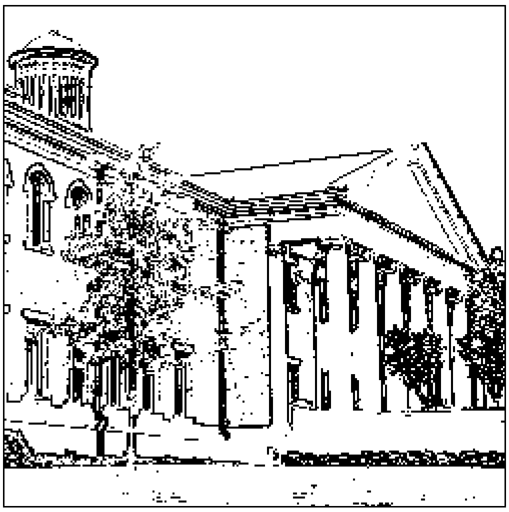
Fig. 6 (a)Well Hall, original image, (b)The result by the proposed algorithm, and (c)by the Sobel operator

Experiment 3: In this experiment, the effect of varying ε on the final image is conducted. The results are shown in Fig.7. As ε varying in increment, more pixels will be exiled out for edge detection, result in poor performance. As shown in Fig.7 (b), (c) and (d), which having $\varepsilon = 0.1$, 0.15 and 0.2, respectively.

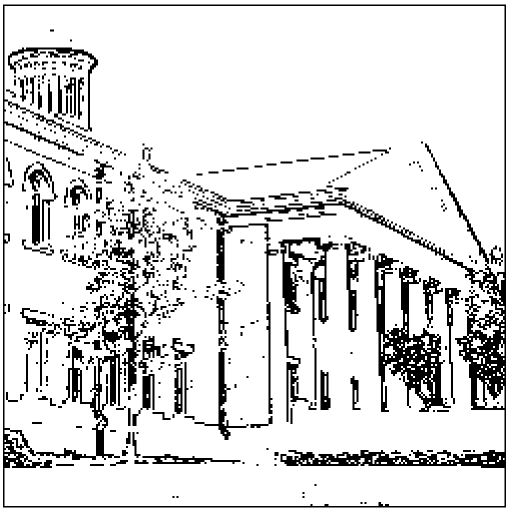
(a)



(b)



(c)



(d)

Fig.7 Effects of threshold value ε, (a)original image, (b)ε = 0.1, (c) ε = 0.15, and (d) ε = 0.2

5.Conclusion

Physical edges are one of the most important properties of objects. They correspond to object boundaries or to changes in surface orientation or material properties. Edges help to extracting useful information and characteristics of an image. In this paper, the application of a new algorithm to the problem of edge detection has been discussed. Edge points are determined by the zero crossing of the logarithm of class ratio of an image, and the length of edge is determined by the distance between two LCRs with opposite sign. A threshold value ε is used to avoid tracking fiction edges. To acquire 2D edges, vertical and horizontal direction edges are founded first, then combine together to get the final result. The advantages of converting 2D problem into 1D problem can greatly reducing the complex of problem solving effort.

Some experiments given in this paper show that the proposed approach demonstrates better performances than the Sobel's edge detector. But, carefully select the threshold value is needed since it controls the performance of the final edged image output. Small threshold value seems to acquire a better edge map, it also prone to deceive by the noise, just as most of the differential edge detectors also behave the same drawback.

REFERENCES

[1]. R. M. Haralick, "Digital Step Edges from Zero Crossing of Second Directional Derivatives", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. PAMI-6, No1, Jan, 1984, 58-68

[2]. V. S. Nallwa and T. O. Binford, "On Detecting Edges", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. PAMI-8, No.6, Nov, 1986, 699-714

[3]. V. Torre and T. A. Poggio, "On Edge Detection", IEEE Trans. on Pattern Analysis and Machine Intelligenc, Vol. PAMI-8, No.2, Mar. 1985, 147-163

[4]. F. Ulupinar and G. Medioni, "Refining Edges Detected by a LoG operator", Computer vision, Graphics and Image Processing, 51, 1990, 275-298

[5]. D. J. Willians and M. Shan, "Edge Contours Using Multiple Scales", Computer Vision, Graphics and Image Processing, 51, 1990, 256-274

[6]. A. Goshtasby, "On Edge Focusing", Image and Vision Computing, Vol. 12, No.4, May, 1994, 247-256

[7]. A. Huertas and G. Medioni, "Detection of Intensity Changes with Subpixel Accuracy Using Laplacian-Gaussian Masks", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. PAMI-8, No.5, Sep.1986, 651-664

[8]. R. C. Gonzalez and R.E. Woods, "Digital Image Processing", Addison-Wesley, New York, 1992

[9]. J. Canny, "A Computational Approach to Edge Detect", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol.PAMI-8, No.6, 1986, 679-698

[10]. T. P. Kaushal, "Visibly Better Edge-Detection Using Observed Image Contrasts", Pattern Recognition Letters, 15, 1994, 641-647

[11]. J.A.Garcia, J. Fdez-Valdivia, A. Garrido, "A Scal-Vector Approach for Edge Detection", Pattern Recognition Letters, 16, 1995, 637-646

[12]. R. J. Qian and T.S. Huang, "Optimal Edge Detection in Two-Dimentional Images", IEEE Trans. on Image Processing, Vol.5, No.7, Jul. 1996, 1215-1220

[13]. R.C.Hardie and C. G. Boncelet, "Gradient-Based Edge Detection Using Nonlinear Edge Enhancing Prefilters", IEEE Trans. on Image Processing, Vol.4, No.11, Nov., 1995, 1572-1577

[14]. A. P. Paplinski, "Directional Filtering in Edge Detection", IEEE Trans. on Image Processing, Vol.7, No.4, Apr. 1998, 611-615

[15]. F. Russo, "Edge Detection in Noisy Images Using Fuzzy Reasoning", IEEE Trans. on Instrumentation and Measurement, Vol.47, No.5, Oct., 1998, 1102-1105

[16]. Wang Linshan, "Prior Estimation for Grey Model GM(1,1)", Journal of Grey System 3, 1991, 129-139

[17]. Hung-Ching Lu and Ming-Feng Yeh, "Some Basic Features of GM(1,1) Model (II) ", Journal of Grey System 4, 1997, 307-321

[18]. H. C. Lu and M. F. Yeh, "Two-Stage GM(1,1) Model:Grey Step Model", The Journal of Grey System, Vol.1, 1997, 9-24

[19]. Chang-Huang Chen, "Grey Modeling of Jump Trend Series", Journal of The Chinese Grey System Association, Vol. 4, No.2, Sep. 2001, 65-71

[20]. LabView and IMAQ user manual, National Instruments