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8—2 Line Segment Detection by High Performance Digital Template Hough Transform DTHT

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Abstract

We are not free from the side effect caused by the digitization of the image also in Hough transform. Since Hough transform detects lines in the expression of the analog line equation, it is finally needed to extract digital line segments from the analog line equations. In this paper, we propose a new method DTHT(Digital Template Hough Transform) to detect digital line segments directly from the digital edge image.

The basic idea of DTHT method is that the digital template of line segment can replace the template line equation in the conventional Hough transform. DTHT can be regarded basically as the new Hough transform with 4-dimensional parameter space indicating a couple of two end points of the segment.

DTHT algorithm can directly detect line segments without post-processing of Hough Transform.

DTHT can perform about 30 times faster than the original Hough transform, and DTHT is important both in theoretical and practical aspects.

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1 Introduction

Hough Transform is one of the most useful methodologies for detecting lines from noisy real images. On the other hand, Hough transform has been inheriting several kinds of unsolved problems caused by the digital implementation of Hough transform on the digital image : quantization problem in the Hough parameter space, threshold selection problem for peak extraction and line segmentation problem from line equation.

This paper proposes a new Hough transform method that can put these fundamental problems into consideration simultaneously. This new method is called Digital Template Hough Transform, DTHT, and DTHT can be regarded basically as a Hough transform for line segment detection with 4-dimensional parameter space.

Since DTHT algorithm extracts edge line segments by means of the direct matching of digital edge image with the digital template of line segment, DTHT algorithm needs no requirement for preparing for the quantization problem of the parameter space, no requirement for tuning the threshold for peak extraction and no requirement for the segmentation of the line.

In spite of the superior properties of DTHT, DTHT would be suffered mainly from the increasing of computation cost and the increasing of the complexity for the detectabilities of line segments.

In this paper, we present DTHT algorithm in Chap.3 basing on the considerations on the basic properties of Hough transform in Chap.2 . Additionally we propose a few countermeasures to decrease the computation cost and the complexity for the detectabilities. It was experimentally demonstrated that DTHT could perform faster than and could extract shorter edge segments more precisely than the original Hough transform.

2 Basic Considerations on Hough Transform

Basic properties of Hough transform for the line detection are briefly summarized in this chapter in order to clarify the principal problems inhering in the Hough basic paradigm.

2.1 How to digitize Hough space — digitization problem —

Hough curves generated by the co-linear points hit a same point (ρ_0, θ_0) simultaneously. On the other hand, for the case of the digital image, edge points on the digitized line do not always generate Hough curves, which hit the same point. Therefore, it is always important to compensate the difference between analog and digital images also in Hough transform.

2.2 How to select threshold for peak detection — threshold selection problem —

Since the height of the peak in Hough parameter space depends on the number of the edge points, as shown in Fig.1, the longer edges lines are more likely to be extracted than the shorter one.

In other words, as experimentally given in Fig.2, almost all edge segments are extracted if the lower threshold is selected and otherwise only the longer edge segments are extracted. Therefore it is indispensable to give a suitable method for selecting threshold for peak extraction.

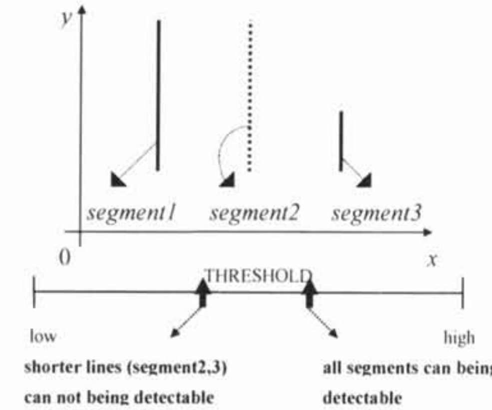

Fig.1 Threshold selection problem for extracting peaks

2.3 Segmenting line segments from the edge image

Since Hough transform provides the line equations as the output, it is always expected to be coupled with the post processor to segment the extracted line into the feasible digital line segments. Although this segmentation algorithm do not exclusively rely on the post processor of Hough transform, it is always necessary to prepare the robust segmentation for the Hough transform.

3 Digital Template Hough Transform

In order to give a breakthrough to the problems of Hough transform shown in Chap.2, a new Hough transform method called Digital Template Hough Transform(DTHT) is proposed. DTHT can extract digital line segments directly from the digital image P.

(a)Input image **(b)Output image(threshold=60)** **(c)Output image(threshold=90)**

Fig.2 Experimental demonstration for the problem of threshold selection

3.1 Basic idea

DTHT draws analog line segment that links a pair of the terminal point candidates in P, and the digital line segment should be extracted only when the pixel density of the digital line segment becomes greater than the threshold.

3.2 Pixel Density

Let the ratio between the numbers of the attention pixels in the digital and analog line segments be the "pixel density" D of the digital line segment. The pixel density D is utilized the measure for evaluating the digital line segment.

3.3 DTHT Algorithm

The basic procedure of DTHT can be summarized as follows :

(*Step*1)After searching the attention pixels $b(X,Y)$ from P, let the terminal point candidates $b_i(X_i,Y_i)$ and $b_j(X_j,Y_j)$ be selected, where $i \neq j$ and $i<j$.

(*Step*2)After calculating an analog line analog segment by eq.(1), let the digital line segment be generated as the template of the matching .

(*Step*3)Vote the pixel density of this digital line segment to the 4-dimensional parameter space.

(*Step*4)Detect the greater votes D than the threshold D_0 as the digital line segments.

$$x = \frac{X_j - X_i}{Y_j - Y_i} y - \frac{X_j - X_i}{Y_j - Y_i} Y_i + X_i \quad (1)$$

High speed and high performance DTHT

4.1 0-count matching

Instead of the matching procedure where the number of $f_{ij}=1$ pixels is accumulated, we introduced new idea to speed up DTHT. The idea is to count up the number of $f_i=0$ pixels. Since in almost all applications of DTHT, the threshold to the accumulation is around 100%, this improvement will improve the cost of computation as shown in Fig.3.

4.2 dividing the image into blocks

By dividing the image into M blocks, it was easy to reduce the computation cost to around $1/M^2$ without fatal degradation of the performance as shown in Fig.4.

4.3 Introducing vote subspace

In order to improve the performance of DTHT, 3x3 pixels around the end-point are utilized to generate 81 templates and the best match among 81 matching was selected.

5 Experiments and Conclusion

Fig.5 shows an example of input image used in the experiments. The image size is 640x480 and the number of edge points is 20628. Fig.6 shows the result of the usual HT. Fig.7 shows the result of DTHT. Fig.8 shows the result of the high speed and high performance DTHT. In the result of usual HT of Fig.5, some segments at the upper left of the image were not detected. Some duplicated detections occurred at every part of the image. As shown in Fig.8, DTHT could detect almost all segments, and the duplicated detection was suppressed. Finally it was clarified that the calculation cost became more

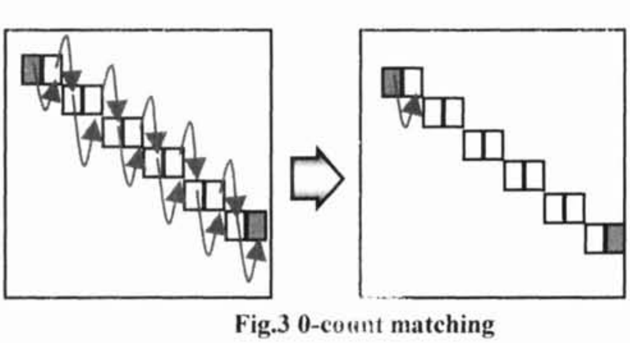

Fig.3 0-count matching

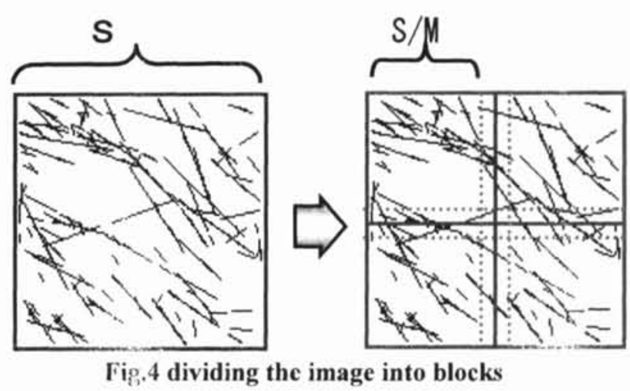

Fig.4 dividing the image into blocks

than 150 times lower than the usual HT.

Acknowledgments

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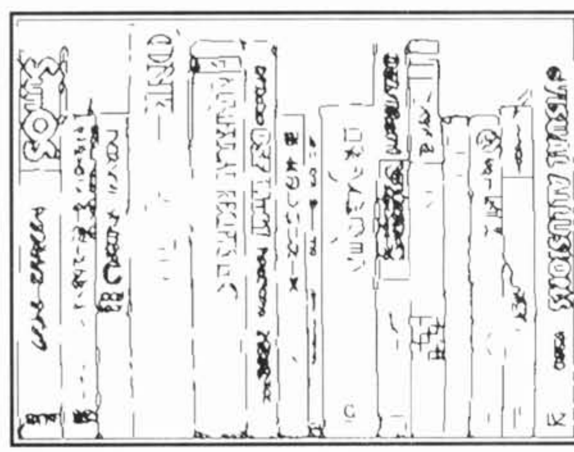
References

[1] K. Kato, K. Murakami and H. Koshimizu. : "Segmentation Algorithm of Lines of Hough Transform using Discriminant Analysis", Proc. ACCV'95, vol.III, pp.191-195(Singapore) (Dec.1995)

[2] J. Hayashi, K. Kato, K. Murakami and H. Koshimizu. : "A Method for Line Segment Detection by Digital Template Hough Transform(DTHT)", Proc. of FCV'97, pp.39-46(Korea) (1997. 1).

[3] M. Morimoto and H. Koshimizu. : "Hough Transform and New Pattern Sensing - Fundamentals - ", J.SICE, vol.35, No.11, pp.869-877(1996.11) (in Japanese).

Fig. 5 Input picture

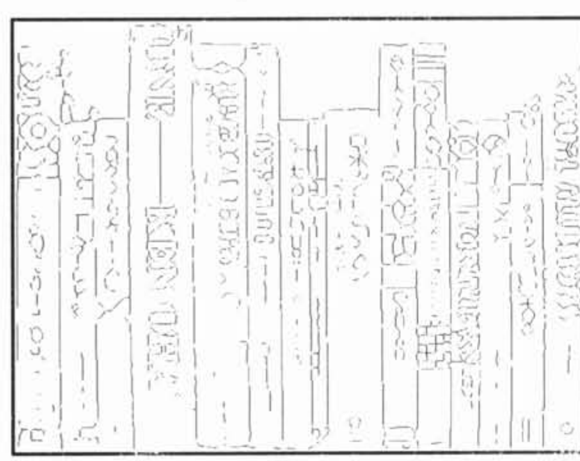


(407. 181sec)

Fig. 7 DTHT

(31. 211sec)

Fig. 6 usually Hough



(0. 202sec)

Fig. 8 DTHT