HOUGH TRANSFORM FOR INTERIOR ORIENTATION IN DIGITAL PHOTOGRAMMETRY

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ABSTRACT

It is known that Hough transform is insensitive to noise and the desired results can be acquired even in the damaged image. Because of its applicability to the image with variations such as rotations or scale changes, Hough transform has been widely used to detect the outlines of arbitrary-oriented and arbitrary-scaled objects such as straight lines or circles. In this paper, we utilized Hough transform combined with the local dynamic thresholding method to accurately locate the center location of fiducial marks. Using detected fidual marks and calibration data, it was possible to determine the calibration coefficients to do interior orientation.

1 INTRODUCTION

Automatically locating the outline of arbitrary objects from digital image has been studied in digital photogrammetry, pattern recognition and other disciplines. Extracting linear features or boundary of the objects is primary task to perform higher level analysis of the input image. Hough transform has been widely used to identify image features such as straight or curved lines (Ballard, 1981). It has also been applied to the variety of pattern recognition of arbitrary oriented and shaped objects (Tzvi and Sandler, 1990; Xu et al.1990).

Many parameters and steps are included to calculate the 3-D coordinates of the object from two stereo image pairs. As the first step of 3-D formation of the object, we perform the interior orientation to accurately establish the relationship between pixel image coordinate system and image coordinate system. There are many interior orientation parameters to be considered. They include atmosphere refraction, camera imperfections, film shrinkage, and scanner error. Important element of interior orientation is to identify the central location of fiducial marks from input digital image. In this paper, we utilized Hough transform combined with local dynamic thresholding method to automatically determine the central location of fiducial marks. Using the detected fiducial marks and calibration data of fiducial marks, the parameters from pixel coordinate system to photo coordinate system using affine transformation are determined.

2 ALGORITHM OF HOUGH TRANSFORM

Hough transform was first proposed by Hough (Hough, 1962). An example to detect straight lines using this method was presented by Duda and Hart (1972). When many distributed points that seem to be in the straight line, the original line can be traced along these points via Hough transform.

One pixel in image space is represented as one straight line in parameter space. Many pixels that are supposed to be straight line in parameter space are mapped many lines in image space. Crossing point of these lines in parameter space is detected as one straight line segment in the image space.

$$y = ax + b \tag{1}$$
$$b = -xa + y \tag{2}$$

Straight line can be represented as equation (1) and (2). However, this parametric model has some difficulties in the representation of vertical straight line, because the parameter tends to go infinity. To overcome this difficulty, Duda and Hart (1972) proposed a polar representation of a straight line.

$$\rho = x \cos \theta + y \sin \theta \tag{3}$$

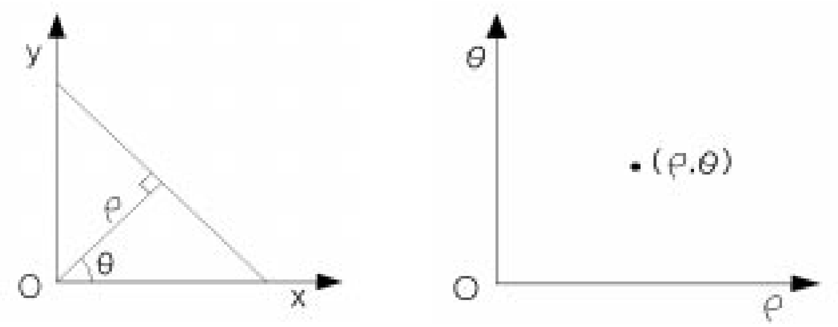


Figure 1. Representation of polar coordinate system

Equation (3) describes a line having direction angle θ at distance ρ from the origin, as can be seen in Figure 1. A straight line passing through the point (x_1, y_1) represents a sinusoidal curve $\rho = x_1\cos\theta + y_1\sin\theta$ in the parameter space (ρ, θ). Collinear points (x_n, y_n) on the binary image space correspond to crossings of sinusoidal curves on the parameter space. Consequently, a similar algorithm to the one described in Figure 1 can be utilized by adapting the model (3) instead of equation (1). The range of the parameters (θ, ρ) is below for an image of size $M_1 \times M_2$.

$$0 < \rho < \sqrt{(M_1^2 + M_2^2)} \tag{4}$$
$$0 \le \theta \le 180 \tag{5}$$

Hough transform for locating the fiducial mark has been performed as the following procedure (Figure 2).

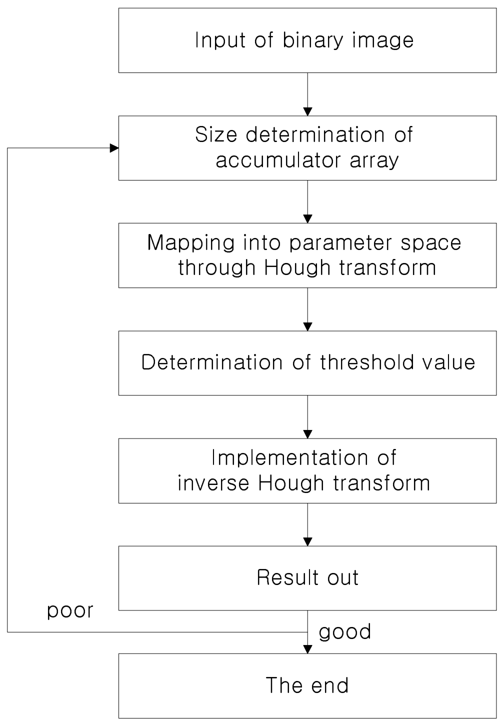


Figure 2. Flowchart of Hough transform procedure.

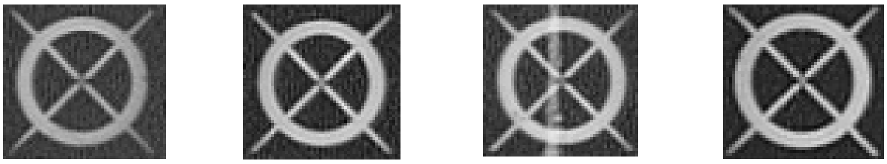
3 SUBIMAGES OF FIDUCIAL MARKS

The aerial photo was taken by Wild RC30 Camera. The nominal focal length is 152.85 mm and scanned aerial image scale is 1:5,000. The diapositives were scanned at a resolution of 600 dpi by VEXCEL corporation's scanner. It was scanned with a pixel size of 42 μm, 8 bits per pixel, yielding a ground resolution 21.2 cm. The total scanned image size is 5481 pixel x 5378 pixel.

For the locating of four fiducial mark using Hough transform, subimages containing fiducial marks are manually extracted. Size and position of each extracted image patch are described in Table 1. Each extracted subimage of the fiducial marks is shown in Figure 3.

Fig No.	Size of Image patch	Image coordinate of patch image in full scene	
Fig 3(a)	55 pixel × 52 pixel	left upper corner	(142, 187)
		Right lower corner	(197,239)
Fig 3(b)	56 pixel × 55 pixel	left upper corner	(5187, 206)
		Right lower corner	(5243, 261)
Fig 3(c)	55 pixel × 54 pixel	left upper corner	(121, 5233)
		right lower corner	(176, 5287)
Fig 3(d)	53 pixel × 51 pixel	left upper corner	(5169, 5255)
		right lower corner	(5222, 5306)

Table 1. Size and position of image patch



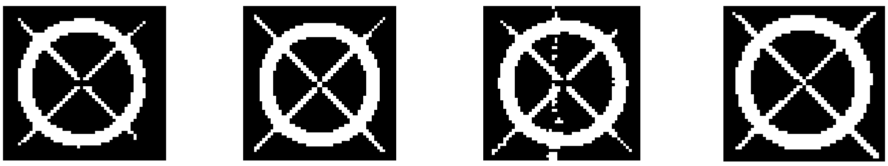
(a) (b) (c) (d)

Figure 3. Subimages of fiducial marks. (a) upper left corner; (b)

4 EXPERIMENTS AND RESULT

We assumed to know the position of the fiducial marks approximately according to the camera type and we extracted manually subimages around fiducial marks as shown in Figure 3. The extracted subimages around the fiducial mark are transformed to binary images for the Hough transform. Simple thresholding technique such as predetermined threshold value is problematic since the threshold value can be varied locally as shown in Figure 3. We implemented local dynamic thresholding algorithm in this research.

The local dynamic thresholding method obtains the local threshold values based on the relative local intensity distribution compared to global thresholding that gets thresholding values based on the whole intensity value. Detail description of the algorithm is presented in Sohn (1996) and the size of local region to estimate bimodal approximation was 8x8. The algorithm automatically converts input images into two classes (foreground and background). The results of the two class images of the input subimages are shown in Figure 4.

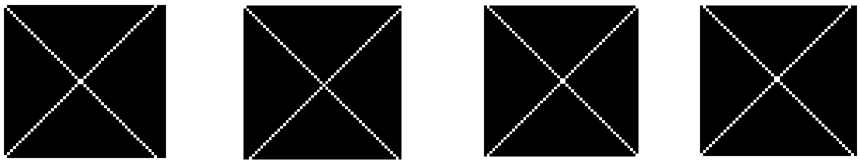


(a) (b) (c) (d)

Figure 4. Binary images of Figure 3 using local dynamic thresholding.

Binary images shown in Figure 4 were used as a basic entry are for the Hough transform. In this research we used only line features to estimate the center of the fiducial marks. Figure 4(c) shows some noises compared to other binary images. With proper selection of θ, the noise element was able to be removed and Hough transform was applied successfully accordingly.

Two peaks represented in accumulator array are mapped into two straight lines. The final results of Hough transform are shown in Figure 5. We calculated the intersection of the lines and obtained the center location of the fiducial marks. Intersections of extracted fiducial marks using Hough transform are given in Table 2. We compared the central location of the automatically detected fiducial marks with manually estimated location. Automatically extracted central location of fiducial marks falls inside the pixel of the manually selected location.



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

Figure 5. The final result of Hough transform

Fiducial mark	linear equation	Crossing point in image patch		Crossing point In full scene	
		X	Y	X	Y
Fig. 5(a)	① y = x ② y = - x + 51	25.500	25.500	167.500	212.500
Fig. 5(b)	① y = x ② y = - x + 56	28.000	28.000	5215.000	234.000
Fig. 5(c)	① y = x-1 ② y = - x + 54	27.500	26.500	148.500	5259.500
Fig. 5(d)	① y = x-1 ② y = - x + 54	25.500	24.500	5194.500	5279.500

Table 2. Intersections of extracted fiducial mark through Hough transform.

We performed affine transformation to relate the calibration data with the location of automatically calculated fiducial marks. Parameters of affine transformation and the results of interior orientation are shown in Table 3 and Table 4, respectively.

Fiducial mark	Calibrated data of fiducial mark		Image coordinate.	
	x(mm)	y(mm)	Column	Row
Fig.5(a)	-106.000	106.000	167.500	212.500
Fig.5(b)	105.996	105.999	5215.000	234.000
Fig.5(c)	-106.001	-106.004	148.500	5259.500
Fig.5(d)	105.999	-105.999	5194.500	5279.500
Parameters of affine transformation			Equations for affine transformation	
a = 0.0420 b = 0.0002 c = -113.08782 d = 0.0002 e = -0.04201 f = 114.91251			X = ax + by + c Y = dx + ey + f	

Table 3. Parameters for affine transformation

Adjusted fiducial coordinates		Residuals in fiducial coordinates	
-106.0168	106.0142	0.0168	-0.0142
106.0128	105.9848	-0.0168	0.0142

-105.9842	-106.0182	-0.0168	0.0142
105.9822	-105.9848	0.0168	-0.0142
Variance of unit weight			
0.000968			
Standard deviation of parameters			
0.0000061652 0.0000061658 0.0283184623 0.0000061652 0.0000061658 0.0283184623			

Table 4. Results of interior orientation

5 CONCLUSION

In this research we demonstrated that finding the position of fiducial mark using Hough transform and local dynamic thresholding algorithm is possible in the scanned digital imagery. We also successfully performed interior orientation with calibration data.

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