Feature Extraction Techniques Using Optical Hough Transform

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Optical Hough Transform 을 사용한 피처 추출 기법

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Abstract

Optical Hough transform technique is introduced to obtain the straight line features in parallel from the input scene images.

Experimental results are also provided to demonstrate the advantage of such optical parallel processor over the digital one. Peaks in optical Hough space are free from quantization noise and thus easy to detect.

1. Introduction

Hough transform (HT) is the well-estabilished method for extracting straight lines from the input images [1]. These straight line features are quite useful for recognizing various objects in the input scene[2]. However, the usual digital HT applided to the quantized input image domain suffers from the quantization noise[3] and also quite time-consuming.

These limitations can be overcome with the introduction of high-speed optical HT architecture processing the edge image in parallel. Optical HT can be achieved either using computer generated holograms (CGH)[4] or using a Dove prism to rotate the input scene. The latter method is relatively simple, provides good performance and enough speed for line extraction, and thus is employed in our experiment.

In this paper, digital HT and examples are addressed in Section 2 and detailed lab data concerning optical HTs and their comparison with digital HTs are also advanced in Section 3.

2. Hough Transfor

2-1. Parametrization of a Straight Line

The straight line HT we consider maps input points (x,y) on a straight line into a Hough space with parameters (ρ, θ) as

$$x\cos\theta + y\sin\theta = \rho, \qquad (1)$$

where ρ is the normal distance from the origin to the straight line and θ is the angle of the slope of the normal line with respect to the + x axis.Each point (x,y) in the image plane is thus mapped to a sinusoidal curve defined by Eq. (1) in Hough parameter space. The heights of the peaks are approximately equal to the length of each line in the image. The origin is located at the center of the image plane and the convention we adopt for the Hough parameters is

$$0 \le \theta < 180^\circ$$

$$\rho \text{ is bipolar and } |\rho| \le \rho_{max} \qquad (2)$$

where $|\rho|_{max}$ is the distance from the origin to the furthest image point belonging to major straight lines to be expected in the input image (it is fixed at 64 since our image resolution is 128 X 128). This particular choice of straight line parameters has the advantage that these parameters are finite if the input image is finite and thus, the Hough space will be also finite. The resolution we use in Hough space is

$$\nabla\rho = 1,\ \theta = 3^{\circ} \qquad (3)$$

2-2. Examples of the Digital Hough Transform

Fig.1 shows two examples of aircraft (DC10) edge images and their HTs. The two test aircraft images with 128 X 128 resolution are drawn on a 2-D plane. The maximum height in each HT plane is normalized to 100 for convenience. The first example (Fig.1a) shows that the two highest peaks occur at $\theta = 0^{\circ}$ in the HT plane. These two peaks correspond to the two parallel fuselage lines.

They also tell us that the aircraft is oriented vertically. The second aircraft is rotated 90° in-plane about its center. The highest peaks now appear at $\theta = 90^{\circ}$, because the two fuselage lines are now parallel to the x axis. This example indicates how easy it is to identify the fuselage lines from the HT plane and to estimate the in-plane orientation of the aircraft. In all HT plots, $\theta=0^{\circ}$ is vertical and θ increases clockwise with positive ρ values always remaining on the same side of the axis along with we are integrating.

The highest six peaks in the second example (Fig.1b) are listed in Table 1. The two highest peaks with the same heights and on the same θ line are the two fuselage lines for the horizontal aircraft.

3. Feature Extraction Using Optical Hough Transform

Most optical HT processors suggested[5] require a 2-D spatial light modulator (SLM). Recently, an optical technique to generate an entire HT using laser diodes and an AO cell has been advanced[6]. This method has speed advantages, easily partitions for different input resolutions, and uses no rotating optics. Its disadvantage is that a polar preprocessing transformation is require (although this is easily generated optically or electronically). Because of ease of assembly and availability of components, we experimented with an HT architecture using rotating optics (a Dove prism). Fig.2 shows our experimental architecture. A green He-Ne laser (λ = 543.5nm) served as the light source. A 10 μm pin hole, 20X objective lens, and a 495 mm lens (L1) were used to collimate the laser beam. A Dove prism is used as an image rotating device and a 495 mm spherical lens (L2) and a 300 mm cylindrical lens (L3) are used to integrate and project the image onto P2. One θ slice of the HT is detected through a horizontal axis slit at P2 with a isometric camera for each orientation of the Dove prism. The aircraft edge images (Fig.3) were used as inputs on film at P1.

Typical light distributions at P2 are shown in Fig.4 when $\theta=90^{\circ}$ (integration horizontally in Fig.3). The two peaks in Fig.4a correspond to the first and second peaks in Table 1 (for the DC10), and each represents a fuselage line in the aircraft image. Fig.4b shows similar HT slices for the Mirage. These outputs (Fig.4) demonstrate the ability to detect fuselage lines from optical HT peaks and that the width of the fuselage for the DC10 is 1.7 times that of the Mirage (as seen from the separation of the two major HT peaks) and that the two fuselage lines are almost of the same lengths for these images (as determined by the height of the two HT peaks). Fig.5 shows the θ=15° HT slice for the DC10. Its peak corresponds to the right rear wing line.

An important issue is a comparison of the accuracy of optical and digital HTs. Experiment results [2] show that the optical HT is free from quantization error and that its peaks are better than digital HT peaks.

4. Conclusion

Optical Hough transform processor employing the rotating optics is built and tested for straight-line extraciton. This optical processor is quite fast due to its inherent parallelism and optical computing nature. Dove prism rotating optics is adopted for its simplicity of the architecture and its good performance expected. Hough transform experement data demonstrating good HT peaks free from digital quantization noise are also provided.

Reference

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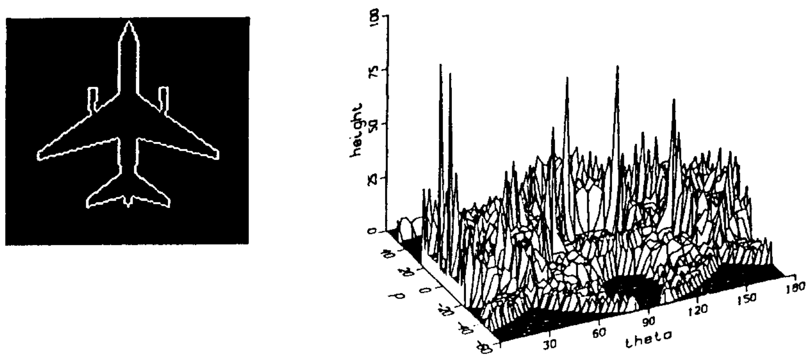
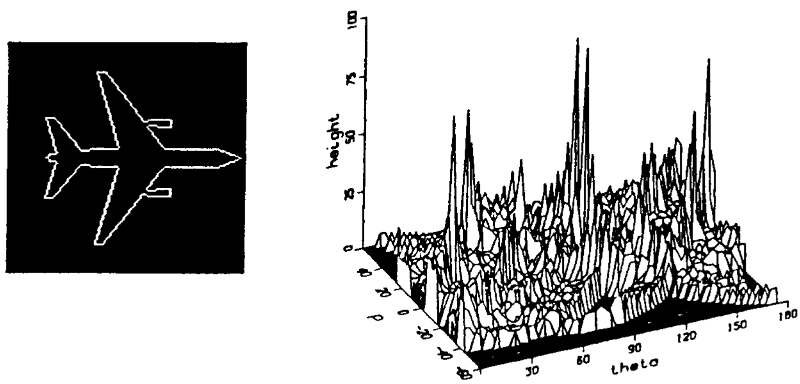
Hough Peak	P (pixel)	θ (degree)	Normalized Peak Height	Object Description
1	-5	90	100	Right fuselage line
2	5	90	100	Left fuselage line
3	-3	15	82	Right front wing line
4	3	165	80	Left rear wing line
5	19	36	72	Left front wing line
6	-19	144	70	Right front wing line

Table 1. The Six Highest Peaks and Their Identification as Found from the Thresholded Hough Space of Fig.1b.



(a) DC10 : Original Contour Edge Image and its HT Plane



(b) DC10 : Original Contour Edge Image and its HT Plane

Fig.1 Two Examples of Hough Transform

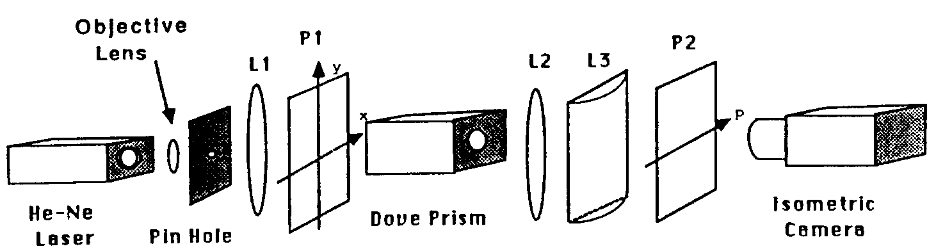


Fig.2 Experimental Setup for Optical Hough Transform

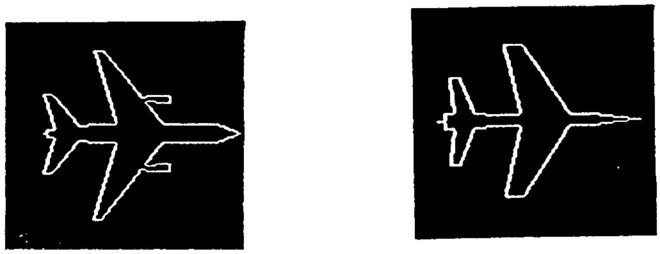


Fig.3 Two Input Images for Optical HT: (a) DC10 and (b) Mirage

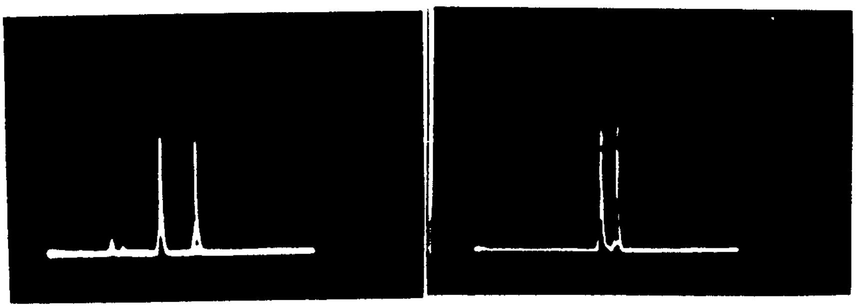


Fig.4 $\theta=90°$ Slice of the HT Obtained from an Isometric Camera: (a) DC10 and (b) Mirage

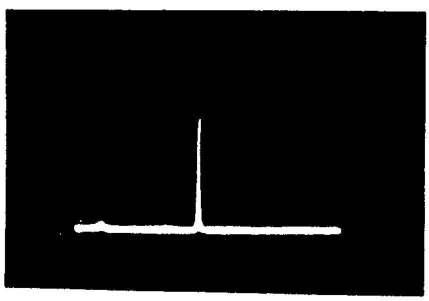


Fig.5 $\theta=15°$ Slice of the HT with the Peak Corresponding to the Right Rear Wing Line of the DC10