IMPROVEMENT AND SYSTOLIC IMPLEMENTATION OF THE HOUGH TRANSFORMATION FOR STRAIGHT LINE DETECTION

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ABSTRACT

Hough Transformation (HT) is an efficient method to detect straight lines in digital pictures. In the conventional HT, pixel contiguity is not accounted for, and this leads to the following drawbacks: (1) actual length of line segments cannot be computed; (2) colinear line segments cannot be distinguished; and (3) very often, false lines are detected and short lines go undetected. This paper proposes a simple and efficient way to perform contiguity check. A systolic architecture that implements this modified transform is presented. The area-time complexity of the proposed architecture was shown to be superior to the conventional sequential algorithm. The modified transform was applied to detect straight edges in a road map and satisfactory results were obtained.

KEYWORDS: Hough Transform, pixel connectivity, systolic array, bucket, area-time complexity.

1. Introduction

Hough Transformation (HT) is an elegant technique for detecting colinear feature points in binary digital pictures [2]. The Hough transform technique has been used successfully in many different applications [3,5-8] that involve detection of straight lines. Using the parameterization proposed by Duda and Hart [2], a straight line in the image plane can be defined by the angle θ of its normal and its algebric distance r from the origin (fig. 1). The equation of the straight line is

$$x \cos\theta + y \sin\theta = r$$

The value of θ is restricted to the interval $[0,\pi)$ and r is restricted to the interval $[-R, R]$, where R is the size of the retina.

In computing the transform, the r-θ space is quantized and represented by a 2-D accumulator array. Each bucket in the r-θ space (r_i,θ_k) corresponds to a bar-shaped window of infinite length and of width Δr in the image (fig. 2). In the conventional HT, each accumulator cell (bucket) records the number of feature points (edge pixels) that fall within the corresponding window. Line segments are located by detecting peaks (local maxima) in the accumulator array.

Three major drawbacks can be be easily observed in the conventional HT:

1. actual length and location of the line segment cannot be obtained;
2. colinear line segments cannot be distinguished; and
3. very often false lines are detected and short lines go undetected.

In applications that require more precise information, such as VLSI photoresist inspection [8], such inaccuraies of the transform are not tolerable. The first two drawbacks are due to the fact that connectivity of the edge pixels is not accounted for in the transformation. The third drawback is due to the inherent shortcoming of the thresholding operation used to detect peaks in the accumulator array.

This paper describes modifications to the conventional HT to account for pixel connectivity and a systolic implementation of the modified transformation. The new transformation will compute the end points of a line segment in addition to the normal parameters r and θ. By checking the contiguity of edge pixels, unrelated pixels (random noise or pixels that actually belong to another line) can be rejected. Each line segment is characterized by its two end points, hence, a bucket can hold multiple colinear lines. Knowing the end points of a line, we can determine the "best" fit to the group of "colinear" edge pixels by counter-checking with the