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A Real Time Generalized Hough Transformation Processor

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Abstract- This paper describes a generalized Hough voting procedure processor which is designed for real time object detection. The processor consists of several processing units. Each unit is assigned to a specific local window area (16x16) of an input image. Generalized Hough voting procedure is executed in each of these areas. The processing unit is implemented by four VLSI chips (called HPE). The VLSI chip is designed for line pattern detection based on the Hough voting procedure.

1. INTRODUCTION

The object detection with structure analysis on symbol character level is effective when the object image is detected by occlusion, shadow, and noise. For this purpose, two process steps shown below is needed.

The first step is to detect, object candidates from image and specify these candidates with several parameters (as "object model candidate").

The Second step is to match these candidates with object knowledge. For example knowledge of shape, color, motion, shape distortion, can be utilized for the analysis. The processor described in this paper is aimed to be used for the first step.

The generalized Hough voting procedure is a matching procedure which matches edge pattern model with the real object image. The line object model is described by several point coordinates (x,y) on the object line, gradient ϕ at these points. The voted value on the Hough parameter space expresses not only the location of the object but also the existence possibility. The matching method, which uses the generalized Hough voting procedure is effective when the target object is a line image. The object candidate is symbolized in the Hough parameter space as to be corresponded to symbol level description, the representation is useful for the second step. Although this procedure is robust for detection from noisy and defective image[1], expensive calculation costs and large amounts of memory are generally required. A hardware is needed to realize a real time processing, which uses the generalized Hough voting procedure for a vision of a mobile robot[2].

2. THE GENERALIZED HOUGH TRANSFORMATION ALGORITHM

The generalized Hough transformation is an extended version of the Hough transformation. The algorithm of this procedure can be applied to arbitrary shaped figure detection. The generalized Hough transformation procedure converts image data in the x-y coordinate system into a object model parameter space similar to the Hough transformation as follows.

[description of object model]

The object model is described by following procedure.

1) Decide reference point location for detecting model description.

2) Calculate the vector r directed from (x,y) to (x_c,y_c), where (x,y) is a point coordinate on model figure and (x_c,y_c) is a reference point and gradient ϕ on the boundary line of model figure.

3) Make R-table shown in Fig.1. This table is described vector r as functions of gradient ϕ.

According this procedure, the object model is represented by the content of R-table.

[transformation algorithm]

Using this table, the possible location of the reference point of the target object (x_c,y_c) is calculated from each point (x,y) of the object image.

$$x_c = x+r(\phi)\cos[\alpha(\phi)]. \quad (1)$$

$$y_c = y+r(\phi)\sin[\alpha(\phi)]. \quad (2)$$

where relation of ϕ, $\alpha(\phi)$, $r(\phi)$, are explained by Fig.2

Finally the locus of the possible reference point location is voted on Hough parameter space from the image.

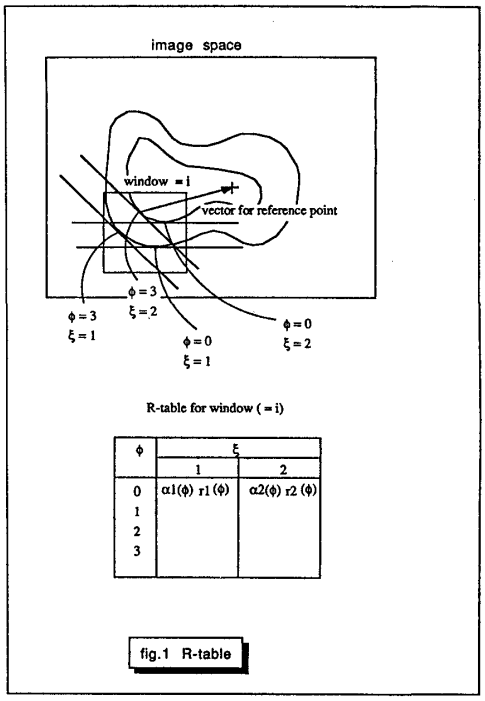

fig.1 R-table

3. THE HARDWARE ARCHITECTURE

The generalized Hough voting procedure processor consists of several window processing units (as shown in Fig.3), and each unit is assigned to one local window area of the input image. The input line image is divided into these windows, the location, size and sampling interval of the processing window can be arbitrarily changed. The single window processing unit consists of four

voting units to which an gradient ϕ direction is assigned. Each voting unit has four units of memory and four sets of 16 counters. The four sets of 16 counters in one voting unit work as the object model parameter space on which the generalized Hough voting is executed for one ϕ direction. The two sets of 16 counters are provided for both of x and y voting space.

The voting unit is implemented by HPE (Hough Parameter Estimator) processor (Fig.4), which detects line patterns within the local window area. The operating speed of this processor is 16 msec/frame.

The architecture of HPE is shown in Fig.4. This chip consists of 16x4 counters and four (16x16) look-up-table memory. The word length of the look-up-table memory is 4 bit. In each look-up-table memory, the value of ρ, which indicates the number of counters to be counted up, is written.Through simulation studies, the processor has been verified to be implemented by a set of VLSIs.

4. CONCLUSION

A real time generalized Hough transformation processor was designed for fast object detection in noisy imagery. Four sets of voting unit made up of 4x16 counters were introduced in the processor for TV rate operation. Through simulation studies, the processor was verified to be implemented by a set of VLSIs(HPE).

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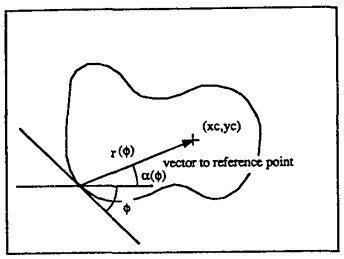

Fig.2 relation of ϕ, $\alpha(\phi)$, $r(\phi)$

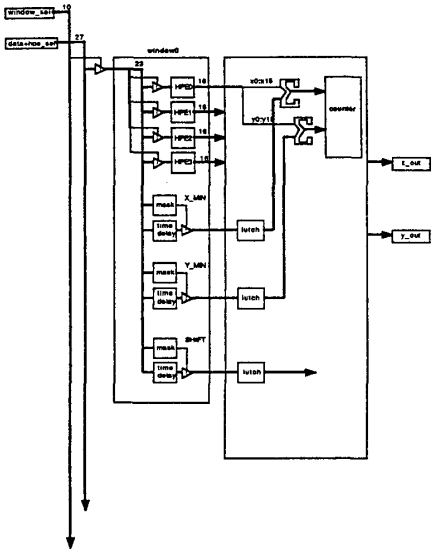

Fig.3 generalized Hough transformation processor with four HPE-LSI

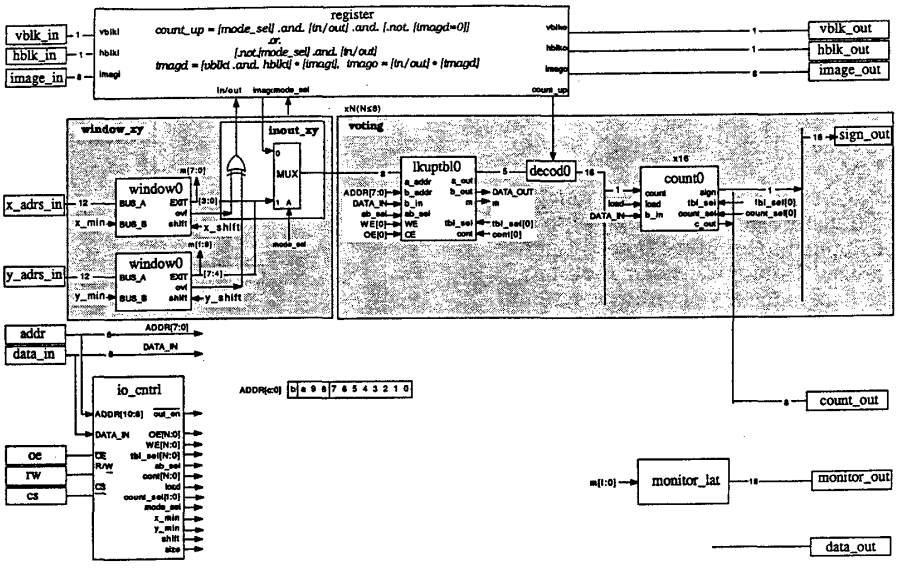

Fig.4 HPE_schema Produced by HITACHI MERL Aug.8.1989