# INVARIANT PATTERN RECOGNITION EXECUTED EXCLUSIVELY IN THE HOUGH SPACE

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**RESUMEN:** Se reporta la creación de un algoritmo computacional basado en la Transformada de Hough, para llevar a cabo reconocimiento invariante con respecto a rotación, traslación y cambios de escala de objetos construidos a partir de segmentos de rectas. Ya que el algoritmo ejecuta todas las operaciones en el espacio (acumulador) de Hough, se consigue una considerable reducción en tiempo de máquina y en complejidad computacional.

Palabras clave: Algoritmo, Visión Cibernética, Visión Computacional, Reconocimiento Invariante de Patrones, Transformada Polar de Hough, Acumulador.

**ABSTRACT:** This paper reports the creation of a computational algorithm based on the Hough Transform and devised to carry out rotation, translation and size-scaling invariant pattern recognition of objects made-up of straight line segments. Since this algorithm carries out all the operations on the Hough accumulator space a considerable reduction in computer time and complexity is achieved.

**KEYWORDS:** Algorithm, Cybernetic Vision, Computational Vision, Invariant Pattern Recognition, Polar Hough Transform, Accumulator Space,

## I. INTRODUCTION

The Hough transform [Illingworth and Kittler, 1988], HT, is a distortion tolerant technique that maps image-space points into curves in a parameter space. In this work the polar, also known as normal HT, is assumed, which maps image-space points of coordinates (x,y) into a parametric accumulator space $(\rho,\theta)$ by means of the equation:

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

The work reported in this paper is based on the following HT properties:

- If a line is rotated by $\alpha$ degrees in image-space then its associated peak in the accumulator is shifted of $\alpha$ degrees along the $\theta$ axis.
- When an object is size-scaled in image-space, only vertical shifts of its associated peaks in the accumulator take place.

The problem of invariant pattern recognition in Hough space has already been addressed by Krishnapuram and Casasent and by Sinha et al. , none of these two works including the treatment of object size-scaling. Those works use convolution in $\theta$-space to achieve the rotational registration between sample objects and the templates, additional processing being necessary to find the translational correspondence.

The method presented in this paper has the following advantages with respect to the methods above mentioned:

- A solution to the problem of object size-scaling invariance is introduced.
- The templates do not need to be originally placed in any particular position or orientation, they can be simply thrown into the image-space.
- The object to be recognized is rotated and translated only once in accumulator space and only then it is compared to the templates. This represents a substantial improvement respectively to the many comparisons implied by the methods used by Krishnapuram and Casasent and Sinha et al.

- The counting in the accumulator peaks is also used as an evidence of pattern matching in the present work.

## II. THE STRATEGY OF THE ALGORITHM

The strategy adopted by the author of the present work to achieve geometric transformation invariant object recognition consists of a basic algorithm that is applied equally to training and recognition stages [Da Fontoura Costa, et al., 1993a, b], [Montenegro, 1993], [Montenegro, 1998].

After Hough transforming the image-space, a set of operations and transformations is carried out in the accumulator, so that 'the object' is taken to a predefined standard position and size in the Hough space, then a characteristic vector T is extracted.

At recognition time, the characteristic vector T of the template object previously extracted at the training stage are compared with the vector S of the sample object to be recognized. The distance between the template and sample vector gives the corresponding likeliness degree. In the case of several objects appearing simultaneously in image-space a pre-processing is necessary to single out individual objects by some of the broadly known labeling techniques.

## III. ACHIEVING INVARIANCE IN PARAMETER SPACE

During training or recognition the object is simply thrown to image-space, in no particular position or orientation. Large instances of the object should be however preferred for the sake of improved accuracy.

### *3.1 The Training Stage*

Every object is presented only once to the system. After Hough transforming the image-space, a set of operations and transformations is carried out in the accumulator, so that 'the object' is taken to a predefined standard position and size in the Hough space, then a characteristic vector T is extracted.

### *3.2 Recognition Stage*

In this stage the same steps carried out at the training stage are performed, now however
a single sample-vector S is created with the corresponding values of $\rho$, $\theta$ , and votation. Once template and sample vectors have been extracted, the Euclidian distance between the vector T and S is computed.

## IV. EXPERIMENTAL RESULTS

The experiment has been carried out using real-life binary objects which had been scanned and stored into 128 x 128 pixel images, see the left-side column in figure 1 where the template object (top) to train (teach) the system and two samples (center and bottom) to be recognized are shown.

The results show that the proposed method successfully takes the input object (template or sample) to a standard size and position from which characteristic vectors can be extracted, this may be appreciated in the right-side column in figure 1 where -for visualization purposes- the region corresponding to the objects in the right column has been shadowed in the reconstruction space.

The template and sample objects presented in this report have been randomly chosen. They have normalized distances of 1.00 and 0.82 respectively to the template object.

## V. CONCLUSION

The problem of geometric-transformation tolerant pattern recognition has been treated exclusively in the Hough accumulator space in a simplified way, which presents potential for considerably reducing the computer time and computational complexity comparatively to other methods that perform the same tasks.

Even though the method has been illustrated with a polygonal object, it is able to deal also with more general objects whose boundaries may be previously approximated by straight lines which do not have to form a closed structure, thus meaning that the method can also be applied to OCR (Optical Character

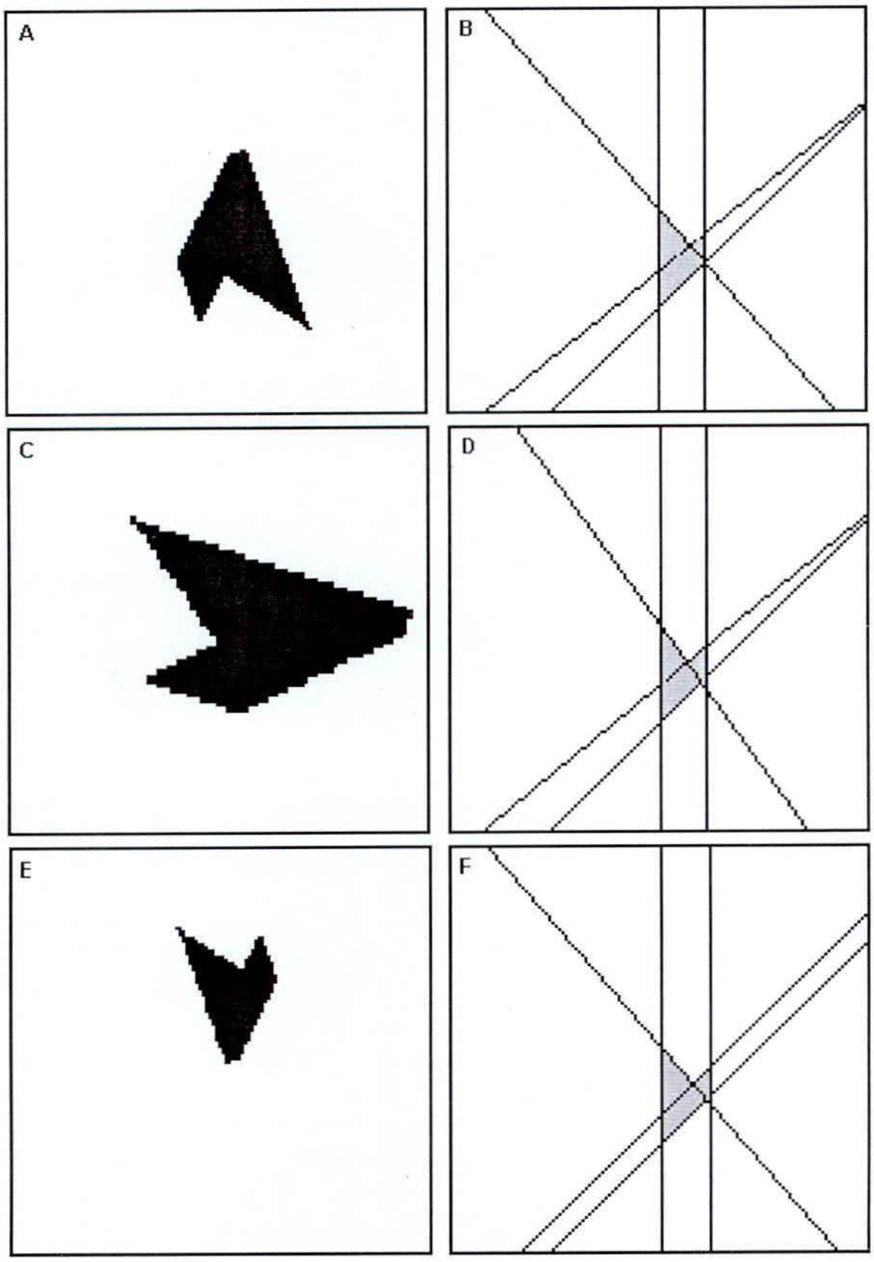


figure 1 - Objects on the left-side column are the objects in image space. Objects on the right-side column are reconstructions from accumulators in standard size and position

Recognition). The potential of this algorithm on industrial automatic quality control applications is evident.

In figure 1: Objects on the left-side column are the objects in image space. Objects on the right-side column are reconstructions from accumulators in standard size and position. In the reconstructions the regions corresponding to the objects have been shadowed for visualization purposes. A: Template object to train the system. B: reconstruction of Template. C and E: Sample objects to be recognized. D and F are sample reconstructions. It can be easily seen that reconstructions from accumulator spaces reproduce almost the same pattern in all cases, this means that no matter the input image size, position or orientation, the system detects a highly similar object in all cases.

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