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A NEW INVARIANT SCHEME FOR THE GENERALIZED HOUGH TRANSFORM

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ABSTRACT

In this work we present a modification of the arbitrary shape detection process based on the pairing of the shape edge points. During this process invariant information of the image is extracted improving the computational requirements of the classical Generalized Hough Transform (GHT). However, the geometry of some shapes makes difficult to pair a enough number of points and can avoid a correct parameter detection. Our technique uses the a priori knowledge of the template shape in order to decide the best criterion for the pairing solving, in this manner, the previous problem.

Key words: Hough transform, parameter uncoupling, invariant characterization, edge point pairing.

1. INTRODUCTION

The generalized Hough Transform (GHT) is a technique that allows us to detect complex patterns in binary images. This method was developed in [1, 2] and uses a reference table that characterizes the template shape. The template reference vectors will be stored in the reference table. Next, the table is superimposed over the image edge points and the reference vectors increment the count of the parameter space position that is being pointed to. The position with a maximum value will indicate a solution.

However, if the image shape is rotated and scaled with respect to the template shape, a more complex computation will be necessary in order to detect it. In this situation, the reference vector will have to be rotated and scaled before the voting process. The complexity of this process will be O(RT·P·Θ· S) where RT is the reference table size, P is the number of image edge points, and Θ and S indicate, respectively, the different orientation and scaling values number that are necessary to apply to the reference vectors. Thus, the computation time using this method will be very high, specially if the variation range for the parameters is large.

In order to improve the computational requirements of the algorithm, other approaches have been carried out. The most part of these implementations are based on exploring some shape invariant characteristics. So, Jeng and Tsai [4], apply transformations to the template in order to obtain rotation and scaling invariant information. This allows them to find the value of the displacement just by using a two-dimensional space. The rotation and the scaling values must be obtained afterwards. However, the computational requirements of this method are still very high. On the other hand, Pao et al [5] using a technique derived from the Straight Line Hough Transform, uncouple the process of obtaining the parameters of the shapes in the image so that the orientation-scaling and displacement values are obtained separately.

Other methods pair edge points so that the information is invariant to the displacement and the scaling. In this way, Guil et al [6] split the detection process into three stages uncoupling the rotation, displacement and scaling detection respectively, achieving a low computational complexity. Yip et al [7], use a similar pairing process in order to vote in a two-dimensional space. The peaks in this space confirm the existence of the shape in the image. Next The parameters are calculated next. However, the main problem of these two methods is that the pairing is carried out between edge points with opposite gradient vectors. This fact restricts the application scope for these two techniques.

In this work we show a new method that permits the detection of all kind of shapes avoiding the above

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mentioned restriction. This method divides the detection process into three stages, as in [6], and uses several tables to store the information obtained by the pairing process. The template and image tables will be compared in order to calculate the parameters of the image shapes.

2. DETECTION PROCESS

The detection of the image shape parameters can be uncoupled extracting invariant information from the image edge points. This one will allow us to compare the new information generated for image and template shapes. At this point, an adequate characterization has to be carried out in order to guarantee good execution times and the possibility of applying the detection process to all kind of image shapes.

In [6] we used an algorithm that paired edge points with anti-parallel associated gradient vectors. Hence, we were able to split the process detection into three stages. The information of the first stage was invariant to the scaling and the displacement and so, the rotation detection was carried out. In the second stage the algorithm detected the displacement using the Fast Hough Transform (FHT) [3] in a two-dimensional parameter space. Finally, in the third stage the scaling was calculated. Actually, the displacement and the scaling detection can be run in parallel due to the two processes are independent.

In [7] a similar pairing technique was developed to obtain the invariant information. However, instead of uncoupling the detection process, they compare the extracted information of the template and image shapes and poll in a 2-dimensional parameter space.

The main problem that these two methods present is the impossibility to detect any kind of shape due to the pairing is only carried out between the edge points with opposite gradient vectors. Thus, if the shape lacks edge points with opposite gradient vectors or the number of them is not enough high, the process detection will not work. In order to solve this problem, we propose the using of other values for the pairings. The selection of these new values will be based on the a priori knowledge of the template shape.

2.1. Edge points pairing

The first aim of the algorithm for shape detection is to transform the image information so as to generate a new orientation invariant description that allows us to calculate the orientation of the image shapes with respect to a template. This new description is based on the comparison between gradient angles of the edge points.

In order to establish the adequate gradient angle difference, ψ, to pair edge points, the template shape is examined. The edge points are stored in a Template Gradient Table (TGT), where the entree $TGT[\theta]$ contains all the edge points which associated gradient vectors have an angle of θ. Then, the different entries in the table are looked through in order to calculate the most adequate value for the pairings. The chosen difference value must satisfy the next condition:

- The most part of the template points have to be used in the pairing process. This one will guarantee a good characterization of the template and a correct detection process even if the image shape is partially occluded.

Sometimes can be necessary to select more than a difference value in order to fulfill the condition, as we will show in the next section.

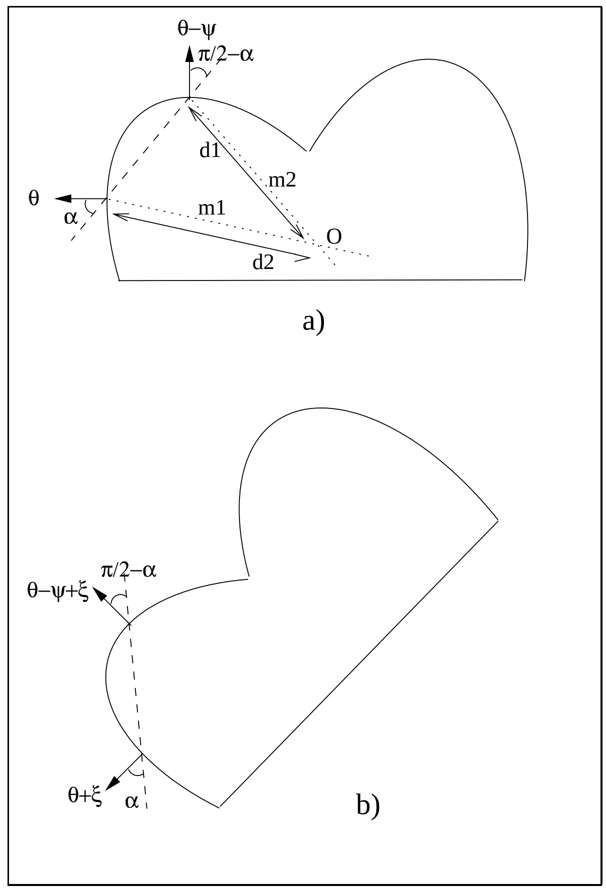

Figure 1: **figure a:** Slope (m_i) and distance (d_i) values for the entree $TDT[\alpha][\theta]$. **figure b:** The α angle remains invariant and the θ angle increments in the rotation value, $\xi = 45°$ (the difference between paired gradient vectors is $\psi = 90°$)

During the pairing process, the angle α between the straight line that crosses the two paired points and the gradient vector of one of these paired points (with gradient angle of θ) is calculated (as shown in Figure 1).

Then in the entree $TDT[\alpha][\theta]$ of the Template Difference Table the next values are stored (Figure 2):

- The slopes (m_1 and m_2) for the lines that join the two edge points with the template reference point. These values will be use during the displacement calculation to generate a bundle of lines that cross the reference point of the image shape. The crossing point will indicate the value of the displacement for the image shape with respect to the template one.
- The distance (d_1 and d_2) between the two paired points. This information will be used for the scale calculation.

All the processing carried out to calculate the template tables is realized before applying the image detection algorithm due to the template is known in advance. Hence, this processing do not affect to the algorithm execution time.

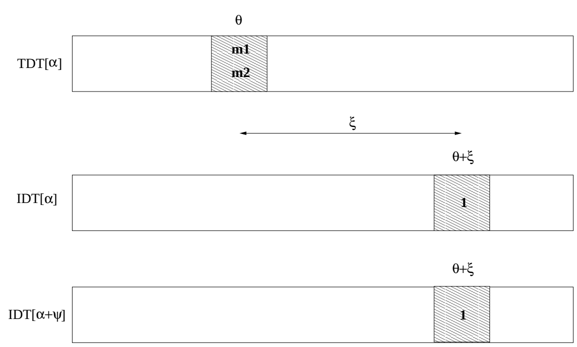

Figure 2: TDT entree for the α and θ angles. The equivalent pairing generates an entree in the $\theta + \xi$ position of the IDT for the rows α and $\alpha + \psi$.

A similar process is applied to the image in order to create the Image Difference Table (IDT), as shown in Figure 2. In this case, the corresponding $IDT[\alpha][\theta + \xi]$ entree will be set to 1 (the reference point for the image is still unknown). On the other hand, the edge point selection for the calculation of the α angle does not allow to know if the equivalent edge point in the template shape was also chosen to create the entree in the TDT. Taking this into account, the entree $IDT[\alpha + \psi][\theta]$ has also to be set.

Note that, in this situation, the set positions for a similar shape in the IDT and TDT are only different by a constant displacement in the rows of the tables (ξ in Figure 2. This displacement will indicate the rotation between the template and image shape. On the other hand, the set positions (not the contents) are invariant to the displacement and the scaling. So, a matching table process [5] can be applied to calculate the orientation angle. When the orientation angle is obtained, the rest of the parameters are calculated according to [6].

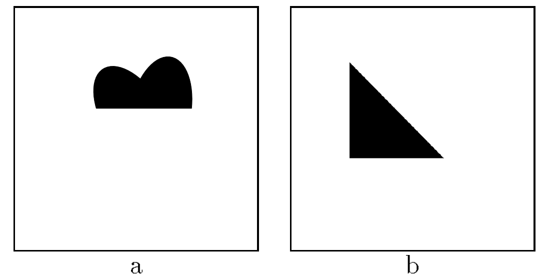

Figure 3: Template shapes for the example

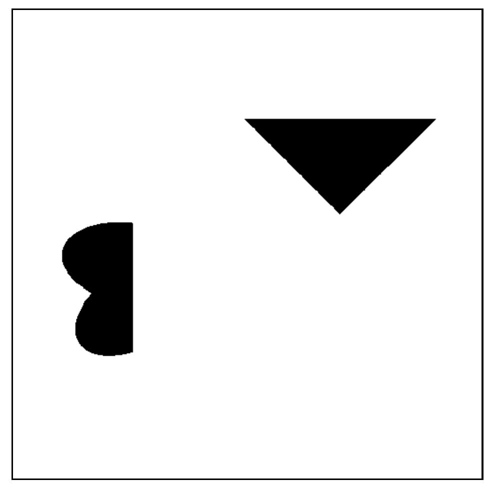

Figure 4: Image shapes for the example. The figures are rotated, shifted and scaled with respect to the template ones.

3. EXPERIMENTAL RESULTS

We show the algorithm results for an image with two different shapes as shown in Figure 4 corresponding to the templates in Figure 3.a and Figure 3.b. The image shapes are rotated, shifted and scaled with respect to the template ones.

In order to detect different shapes, the algorithm has to be applied sequentially for each shape. Hence, the heart and triangle shape have been processed in first and second place respectively.

As it can be observed, the heart shape is not complete. Thus, the number of paired points using the criterion in [7] (opposite gradient vectors) will be too short to generate a clear peak in the voting space. Using the TGT of the heart shape, a difference angle of $\psi = 90°$ has been chosen. In 5.a the voting results are shown. A clear 0 appear for a rotation angle of 90°.

On the other hand, using only a difference angle the pairing for the most part of edge points in the triangle shape can not be carried out. Hence, we have chosen two different difference angle. One of them is 90°. With this value, all the edge points that belong to the triangle legs will be pairing. The other one is 135° that allows the pairing between points from one of the triangle legs and the hypotenuse. In 5.b we can see the voting results for the triangle. A 0 appear at 45° that corresponds to the rotation angle.

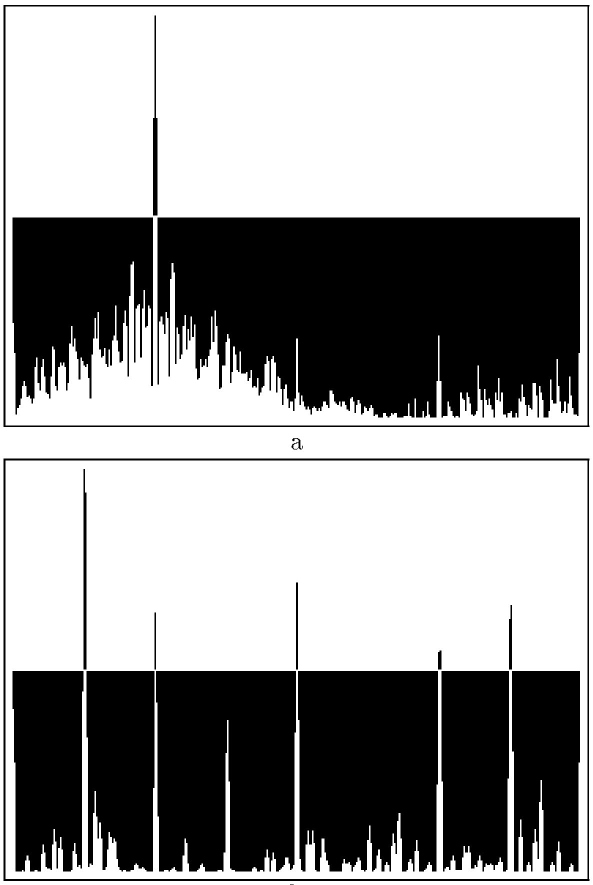

Figure 5: Voting for the heart shape (a) and triangle shape (b).

4. CONCLUSIONS

A new algorithm have been presented to detect arbitrary shapes using the GHT. This algorithm generates invariant information in order to 0 the parameter calculation (orientation, displacement and scaling) saving, in this manner computation. The new shape characterization is calculated from a point pairing process based on a priori template shape acknowledge. This new technique allows to extend the kind of shapes that can be detected.

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