Research on Object Shape Detection from Image with High-level Noise Based on Fuzzy Generalized Hough Transform

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***Abstract*—Hough transform has been applied abroad in object shape detection. However, the traditional generalized Hough transform may not make the vote focus to one point when the image has a high-level noise. As a result, the object positioning is not very precise, or even wrong. It makes the Hough Transform can't be used in strong noisy image or complex object background on this condition. In this paper, we apply fuzzy set theory to generalized Hough transform and use a new method to process strong noisy image. The method regards the unfocused area not just as some simple point but a "fuzzy voting point"—a fuzzy area. Consequently, the fuzzy set theory can be used to describe the "fuzzy voting point". By constructing a new subjection function, we can calculate a cut set and use it as weight to optimize the position of the reference points. The experiments show that this method can get more accurate and robust object position than traditional method in shape detection from high-level noise image.**

Keywords-Object Shape Detection; Fuzzy Set; Generalized Hough Transform; Fuzzy Voting Point; Subjection Function

I. INTRODUCTION

The shape characteristic belongs to an advanced visual characteristic, which has some semantic information in it. The shape characteristic has a better ability to distinguish and identify the objects in contrast to the color and texture characteristic.

Presently, in the shape detection of image, the shape of objects is described through the edge characteristic and the object we studied is usually regarded as a close curve. However, there` s some difficulties in picking up an integrated and well closed edge of the object because of the influence of noise, shadow, shelter or other factors. The Hough transform is a "voting" arithmetic which has a better way in dealing with the problems such as noise, shadow, or the shelter of the object. And also it has been widely used in the object shape detection [1][2]. But if the noise is too strong or the background of the object is too complex, the traditional generalized Hough transform may not vote to a focus. This paper is just about the mentioned problem.

II. THE PRINCIPLE OF HOUGH TRANSFORM

A. The standard Hough transform

Hough transform is put forward by Hough in detecting the curves, for example, beeline, round, ellipse, parabola and so on, which can be described in a certain function in the image. This method is first used in picking up beelines by Duda and Hart in 1972 [3]. The principle of Hough transform is mainly about how to change the curvilinear points in the image space into the parameter space, and detect the curves` descriptive parameters by judging the maximum values in such parameter spaces.

Take the beeline detection as an example. In the image space X, Y, the beeline` s equation is:

$$y = ax + b \qquad (1)$$

Its pole coordinate is:

$$\rho = x\cos\theta + y\sin\theta \qquad (2)$$

According to this equation, a point in former image can be mapped into an approximate sinusoid in the parameter space. And points in a beeline in the image

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space which are mapped into the parameter space must be a set of sinusoid having a same point of intersection. Hough transform change the detection in image space into the parameter space and finish the detection by a kind of simple cumulative statistic in the parameter space. Theoretically, all the curves that can be described in analytic expressions can be detected by Hough transform.

B. Generalized Hough transform

In the actual object shape detection, the analytical expressions of many objects` edge are hard to get, or even of inexistence. In this situation, generalized Hough transform can offer several methods to solve this problem. Generalized Hough transform is an upgrade from Hough transform. The difference between them is that the analytical expression for curves is different. It constructs a discrete "object outline parameter descriptive table" by the object swatch detected in the course of study. This table can replace the curve` s analytical expressions in Hough transform [4]. And from this, Hough transform can be used to detect every anomaly objective shape.

Constructing a referenced table is that it associate every edge point of the object with the referenced points (x^R, y^R) which have been selected. For every edge point (x, y), three values can be figured out: the angle α between the direction of the line from edge points to referenced points and the direction of the X axis; the grads angle ϕ of this point; the Euclidean distance r from this point to the referenced point. Take picture 1 for example:

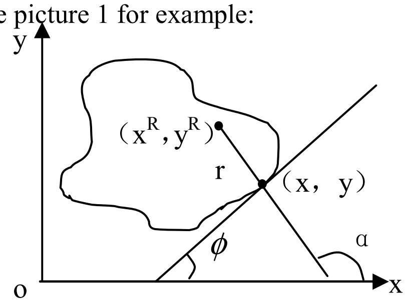

Figure 1. Geometric relation between the referenced point and the edge of object

Different edge points may have the same grads direction, that is to say, a single ϕ can correspond to several (r, α). Therefore, R-table can be constructed using ϕ as an index. Take table 1 for example:

TABLE 1. R- TABLE

ϕ_1	(r_{11}, α_{11}), (r_{12}, α_{12}),…, (r_{1n}, α_{1n})
ϕ_2	(r_{21}, α_{21}), (r_{22}, α_{22}),…, (r_{2n}, α_{2n})
ϕ_3	(r_{31}, α_{31}), (r_{32}, α_{32}),…, (r_{3n}, α_{3n})
…	……
ϕ_k	(r_{k1}, α_{k1}), (r_{k2}, α_{k2}),…, (r_{kn}, α_{kn})

In the objective shape detection, take the grads angle ϕ of every edge point as index, and calculate the potential referenced point according to every (r, α) in the R-table. Meanwhile, use accumulator to make a statistic, and then, the shape detection finish. Because the relationship between the referenced points (x^R, y^R) and the shape has been known, the position of this detection can be confirmed uniquely.

III. THE THEORY OF FUZZY SET

Fuzzy set has another name F set. It can be used to describe fuzzy phenomena, and be widely used in the area of pattern recognition [5][6]. Suppose in the area X, fuzzy set $\tilde{A}$ means that for every $x \in X$, there is a number $\mu_{\tilde{A}}(x)$. This number is called subjection degree from x to $\tilde{A}$.

And $\mu_{\tilde{A}}(x) \in [0,1]$. For $\mu_{\tilde{A}}$, there are such mappings:

$$\tilde{A}: \quad X \to [0,1]$$

$$x \mapsto \mu_{\tilde{A}}(x)$$

$\mu_{\tilde{A}}(x)$ is called a subjection function to $\tilde{A}$.

A fuzzy set can be determined by a LUN area X and a subjection function. That is $\tilde{A} = < X, \mu_{\tilde{A}}(x) >$. If there is at least one element x whose subjection degree is 1, the fuzzy set is standard. When the fuzzy set only has two values: 0and 1, it degenerates to a ordinary set.

Suppose $\tilde{A} \in F(X)$, $\forall \lambda \in [0,1]$, it is called ordinary set.

$$A_\lambda = \{x \mid x \in X, \mu_{\tilde{A}}(x) \geq \lambda\}$$

$A_\lambda = \{x \mid x \in X, \mu_{\tilde{A}}(x) \geq \lambda\}$ is $\lambda-$ cut set to $\tilde{A}$. λ is called believing level.

IV. THE DETAIL OF THE METHOD

Fuzzy Generalized Hough Transform is short for FGHT. It is an arithmetic which brings fuzzy set into Hough transform. First, the image carries on a pretreatment in order to get an edge image using FGHT to realize shape detection. This paper introduce a method called Otsu, which divide the image and then carry on the edge extraction, and meanwhile, improve the values. From this a two-value edge image is got.

A. The construction of R-table

After the referenced number (x^R, y^R) of the object model confirmed, every edge points (ϕ, r, α) need to be calculated to construct a R-table. r and α can be calculated from their definitions by using the referenced points ($x,^R y^R$)and outline points (i, j). Suppose the ash-degree function of the image is $f(i, j)$. i and j is the row and line coordinates of the pixel. The formula for calculate the grads direction is as follows:

$$f_x(i,j) = f(i,j) - f(i-1,j) \tag{3}$$

$$f_y(i,j) = f(i,j) - f(i,j-1) \tag{4}$$

$$\phi_{i,j} = \arctan\left(f_y / f_x\right) \tag{5}$$

For the digital image that we dispose, the grads direction of every point has been changed into a finite value. By reason of different adjacent area have different directions, we commonly only take 4-adjacent area and 8-adjacent area into account. And constructing 4 or 8 fabric variables reduces the storage values [7]. Apparently, there are some (r, α) in every structure.

B. Unit vote for accumulator

Firstly, one…array $A(x^{\mathrm{R}}, y^{\mathrm{R}}, S, \tau)$ which show potential referenced points need to be defined. And every element should be initialized to 0. Here, x^R, y^R is the coordinates of the potential referenced points that we want. τ is rotary gene and S is zoom gene.

Secondly, calculate the grads direction $\phi_{i,j}$ of current edge point (i, j). (r, α) can be found in R-table.

Thirdly, use formula (6) and (7) to get x^R, y^R:

$$x^R = x + r(\phi) S \cos(\alpha(\phi) + \tau) \tag{6}$$

$$y^R = y + r(\phi) S \sin(\alpha(\phi) + \tau) \tag{7}$$

Finally, for each (x^R, y^R), vote for the corresponding accumulated unit $A(x^{\mathrm{R}}, y^{\mathrm{R}}, S, \tau)$ cumulatively.

C. Fuzzy optimizement of referenced points

Theoretically, the coordinates of the referenced points will vote to a point of the calculator unit. The accumulated ballot of this point will be apparently larger than other points, and so we can realize the object orientation by finding the max of accumulated number. In fact, as a result of the noise, shadow, angle of image and other influence, the same object may have some differences in different edge images. This leads to a problem of unfocused voting. There will be some orientation errors if only taking the max of the ballot into account.

When the voting is unfocused, there will be a "high voting area". We can take this as a "fuzzy voting point". And then we can describe it with the fuzzy theory in order to optimize it[8]. The method of the optimization is as follows:

Step1. Find "high voting area". Define a small window and remove this window in the parameter accumulators. Calculate the ballot of this window area.

Step2. Constitute a fuzzy set $\widetilde{A}$. Take the ballot as the LUN set X, and constitute a fuzzy set with the x_k from "high voting area" as elements.

Step3. Construct a subjection function $\mu_{\widetilde{A}}(x_k)$. Considering the importance of the highest ballot in the small window, the subjection function is defined as follows:

$$\mu_{\widetilde{A}}(x_k) = (1 - \frac{D}{L}) \frac{x_k}{x_m} \tag{8}$$

D is the Euclidean distance from the position of the accumulator unit to the position of the highest ballot in small windows. L is the size of the small window. x_m is the highest voting number of the small window.

Step4. Calculate $\lambda -$cut set from $\widetilde{A}$. Here, λ is an experienced value. It is related to some factors such as the noise of edge images, the size of the small window and so on. In this paper, λ is 0.5.

Step5. Optimize the position of referenced points. Get x_k^R, y_k^R from every element in the $\lambda -$cut set, and take the subjection degree of its fuzzy subset as a power. Then carry on weighted mean and get the optimizing referenced points.

Because the relationship between the object model and the referenced points, the objective shape detection can be realized after getting the referenced points.

V. EXPERIMENT RESULT AND THE ANALYSIS

In order to validate the robustness of this paper's method, we simulated an image with high level of noise like figure 3 :

I

Figure 2. Object image

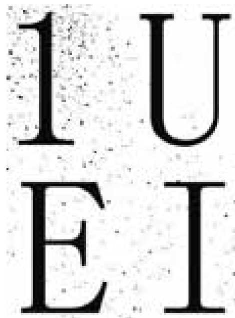

Figure 3. Image for detected

(a) The result of taditional method

(b) The result of this paper's method

Figure 4. The contrast between the results of this paper's method and traditional method

Figure 4 show the contrast between the results of this paper's method and traditional method. From image (a) of figure 4, it can be found that the object image "I" has not be detected as "I" in correct position, but as "1" in wrong position. The image (b) of figure 4 shows that this paper's method gives a correct object shape detection result.

VI. CONCLUSION

Generalized Hough transform has been widely used in the object shape detection. However, if the image has a high-level noise or the background of the object is too complex, the traditional generalized Hough transform may not vote to a focus and then may give wrong detection result.

This paper constructs a novel subjection function and we use it to optimize the position of the reference points. The experiments show that this method can get more accurate and robust object position in shape detection from high-level noise image than traditional method.

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