An Effective Image Matching Algorithm Based on Rotation Independence

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***Abstract*—Traditional image matching algorithms has poor accuracy in image comparing, such as histogram intersection method. A new image matching algorithm based on the similarity comparison of irregular shape is presented in this paper, which divides the image into a number of irregular regions according to different colors, and extracts the boundary points of the irregular region to compose an irregular shape. The direction and distance is used to comparing the two irregular shapes if the rotation of the image is not considered, otherwise circular list is used to ignore the image rotation. It can be used widely. If two irregular shapes are similar, the two images are considered similar. Experiment proves that this method can effectively improve the image matching accuracy.**

Keywords-Image matching; irregular shape; blocking; rotating-independence, circular list

I. INTRODUCTION

The traditional color histogram method only records colors and the proportion of each color in the image. The two images with the same color histogram may be variety greatly in content because it ignores the color space distribution information of the image. Therefore, the algorithm can't meet user's needs well in image retrieval.

The block color histogram matching algorithm is proposed to overcome the shortcomings of the traditional histogram method. An image matching method based on nine sub-block color histogram is proposed in references [1]. An optimized block color histogram method is proposed in reference [2], image overlap block is introduced. This method compensates for the defects of losing the global information caused by overlooking image block edge information. It is very effective for images which contents concentrated in the middle of the image. It does not play a role in contents marginalized distribution image.

II. THE IMPROVEMENT OF IMAGE MATCHING ALGORITHM

The idea of the image matching method based on the sub-block irregular shape similar comparison is: First, to divide the image into more sub-regions corresponding with their colors using an image dividing algorithm, and record its relative position in the original image; Then, to compare the corresponding small regions in two images respectively, if the colors in the two regions are same or their color difference is smaller than a given value, the shapes are similar, and their relative positions in their original image are substantially same, the two sub-regions are considered similar; Finally, two images are considered similar when their corresponding sub-regions in the two images are similar.

A. The Automatic Irregular Region Blocking Method

An image contains a variety of colors. A new region growing algorithm is introduced to divide an image into multiple different regions of color according to the different colors. The basic idea of the region growing algorithm is: together the pixels of a similar characteristic to form a contiguous area. As start of the algorithm, finding a seed pixel as a starting point for the growth of the seeds, and then merged the pixels around the seed having the same or similar properties into the region of the seed pixel. Each pixel which is merged into this area is treated as a new seed. The process is repeated until the condition is not satisfied. In this way, a sub-region is formed.

Region growing algorithm is applied to divide image, the process can be summarized as follows:

(1) Randomly select a pixel in the image to be divided, set its color value is C_n, the point is seen as the center of a cluster O_n.

(2) Take adjacent pixel's color in each direction (assuming the pixel is P_i, $1 \le i \le 8$, its color value is C_i), and compare them with the color value of the center point O_n. The color difference is calculated as follows:

$$D(C_i, O_n) = 1 - \exp[-\frac{E(C_i, O_n)}{\gamma}] \quad (1)$$

(3) If the color difference is smaller than the set threshold, then merge P_i into the cluster of O_n, and modify the color values of the new cluster center; Then continue computing the color difference of the next adjacent pixels in the direction along with $O_n \to P_i$ with the center point O_n. If the color difference is greater than the set threshold, go to step (4).

Whenever a pixel is merged into a cluster, modify the color values of the cluster center timely. The color values of the cluster center can be expressed as the average color value of all pixels in the clustering. Calculation formula is as formula .2, wherein, N is the number of pixels in the cluster.

$$\overline{C_n} = \frac{1}{N} \sum_{1 \le j \le N} C_j \quad (2)$$

In an image, the next adjacent pixel in the direction from O_n to P_i can be obtained through the pixel coordinates of the point.. Assumed the coordinates of O_n is (X_{Cn}, Y_{Cn}), the coordinates of P_i is (X_{Pi}, Y_{Pi}).

if $X_{Pi} > X_{Cn}, Y_{Pi} = Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}+1, Y_{Pi})$;

if $X_{Pi} > X_{Cn}, Y_{Pi} > Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}+1, Y_{Pi}+1)$;

if $X_{Pi} > X_{Cn}, Y_{Pi} < Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}+1, Y_{Pi}-1)$;

if $X_{Pi} = X_{Cn}, Y_{Pi} > Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}, Y_{Pi}+1)$;

if $X_{Pi} = X_{Cn}, Y_{Pi} < Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}, Y_{Pi}-1)$;

if $X_{Pi} < X_{Cn}, Y_{Pi} = Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}-1, Y_{Pi})$;

if $X_{Pi} < X_{Cn}, Y_{Pi} > Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}-1, Y_{Pi}+1)$;

if $X_{Pi} < X_{Cn}, Y_{Pi} < Y_{Cn}$, the next adjacent pixel in the direction $O_n \rightarrow P_i$ is $(X_{Pi}-1, Y_{Pi}-1)$;

(4) If the color difference is larger than the set threshold, the point P_i is thought as the boundary point of this cluster, recording its coordinates and color, and regard it as a new cluster center O_n+1.

(5) For each cluster center, repeat step 2 to step 4, until each pixel in the image have been processed, and the color value of each cluster center is no longer changed.

Based on region growing algorithm [6], the adjacent pixels can be classified into a set, which their color difference is smaller than the setting threshold λ. The pixels in the image in the same set form a continuous area. The pixels which color difference is greater than the threshold λ compose a new area, taking a random pixel as a new starting point.

When every pixel of the image is processed, the image is divided into multiple regions of different color. Typically, the spatial distribution of a color in an image is no law; therefore, the blocks obtained are irregular regions in accordance with the color segmentation.

B. Representation of the Irregular Shape

The colors of the pixels in the same region are the same or their color difference is small according to the automatic region blocking method. Every irregular area can be seen as "density" uniform area. An irregular area can be thought as an irregular shape having a specific color. It can be expressed as a set of all coordinates of boundary point. Setting an irregular shape has n boundary points, using $E = \{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$ to record the coordinates of all its boundary points. The center coordinates $f(x_0, y_0)$ can be computed through the average transverse and longitudinal coordinates for all the boundary points. Calculated as follows:

$$x_0 = \sum_{i-1}^{n} x_i \Big/ n \text{ , } y_0 = \sum_{i-1}^{n} y_i \Big/ n \qquad (3)$$

The center of the shape can be represented by $F(X_0, Y_0)$; assuming the image length is L, width is W, then the vertical and horizontal coordinates of F can be expressed as: $X_0 = x_0/L$, $Y_0 = y_0/W$, its color is C, the irregular shapes can be expressed as follows:

$$I = \{F(X_0, Y_0), f(x_0, y_0), E, C\} \qquad (4)$$

C. Similar Comparison Method of Irregular Shapes Based on Direction and Distance

The idea of similar comparison of two shapes is comparing the difference of the distances between boundary points and their respective center point in the same directions of the two irregular shapes. If the differences are less than setting threshold in all directions, the two shapes are similar. Follows give some definitions.

Definition 1: quadrant. establishing a Cartesian coordinate system for the origin to the center of the irregular shapes, irregular shapes are divided into four regions, counterclockwise rotation from the upper right area of the quadrant, followed by the first, second, third, four-quadrant.

The vertical and horizontal coordinate difference Δx, Δy between the point and its center must be calculated firstly to determine a boundary point (x_i, y_i) belongs to which quadrants, which $\Delta x = x_i - x_0$, $\Delta y = y_i - y_0$, quadrant N is computed as follows:

When Δx>0, Δy>0, N = 4; When Δx<0, Δy>0, N = 3;

When Δx<0, Δy<0, N = 2; When Δx> 0, Δy<0, N = 1.

Notes: the axis to the right for the X-axis positive direction, down to the Y-axis positive direction;

Definition 2: The relative angle between the center and the boundary point. the angle of the line connecting the boundary point and the center to the horizontal line over the center. The angle can be computed by arc tangent, which is by computing the tangent firstly in this paper.

To determine whether the directions of a boundary point relative to its center in two irregular shapes point are same, the tangent of the angle of the boundary points relative to its center and the quadrant of the boundary points are compared. Assume A and B are the two irregular shapes, the boundary point are respectively $A_i(A_{xi}, A_{yi})$ and $B_i(B_{xi}, B_{yi})$, the central point is respectively $A_{f0}(A_{x0}, A_{y0})$ 、 $B_{f0}(B_{x0}, B_{y0})$.Whether the direction of A_i relative to A_{f0} and the direction of B_i relative to B_{f0} are the same can be judged as follows:

(1) calculate the tangent T_{Ai} of the boundary points A_i relative to the center A_{f0}, $T_{Ai} = |\Delta x/\Delta y|$, and the tangent T_{Bi} of the boundary points B_i relative to the center B_{f0};

(2) Comparing the tangent values T_{Ai} and T_{Bi}, as well as the quadrants N_{Ai} and N_{Bi}, if the difference between the two tangents is less than the setting threshold, and also the two quadrants are equal, then the directions of the points A_i and

B_i are considered to be the same, otherwise, they are different.

Definition 3: The distance between boundary point and the center. defined as the Euclidean distance, calculated by formula 5, Assume the boundary point is $A_i(A_{xi}, A_{yi})$ and the center point is $A_{f0}(A_{x0}, A_{y0})$, the distance is D_{Ai}.

$$D_{Ai} = \sqrt{(Ax_i - Ax_0)^2 + (Ay_i - Ay_0)^2} \quad (5)$$

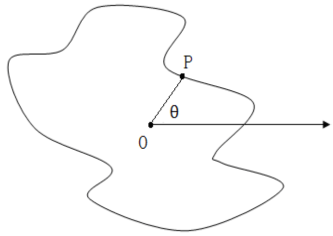
Whether the two irregular shapes A and B are similar can be determined by the difference of the distances between the boundary points and their relative center in two irregular shapes is less than the setting threshold or not. If the difference is greater than the threshold, indicating the two irregular shapes is not similar because of the relative position of the two irregular shapes is not same in the original image, Otherwise, select the boundary point A_i from the shape A (assuming A has n boundary points, 1 ≤ i ≤ n), and choose a boundary point B_i from the shape B (assuming B has m boundary point, 1 ≤ j ≤ m), judge Whether the direction of A_i and B_i are the same or not, and the difference of the distance D_{Ai} and D_{Bi} is less than the setting threshold or not. If yes, continue the other boundary points, until all boundary points are computed. If all the distance differences in the same direction are less than the set threshold, the two irregular shapes are considered similar; otherwise, they are not similar.

The idea of similar comparison method of irregular shapes based on direction and distance is clear, it is relatively simple to implement; and regardless of the size, and it has better retrieval efficiency in image retrieval. However, this method also has a drawback of not considering rotation of the image. Shortcomings in the method can be further improved by the following method, an irregular shape similar comparison based on rotating independence.

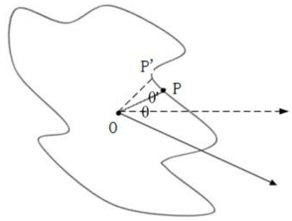
D. Similar Comparison Method of Irregular Shapes Based on Rotating Independence.

If we don't consider the rotation of the shape, we can compare the difference of the distances between boundary points and its center in the same directions of the two irregular shapes. If the differences are less than setting threshold in all directions, the two shapes are similar. But In most cases, this method is not applicable. The similarity comparison method based on the rotation independent is proposed to overcome the impact of the rotation on the shape similarity comparison. For the two irregular shape (assuming a target shape and a collation shape), respectively, recording their boundary and center points; Next, from an angle of 0 ~ 360°, computing each distance of each boundary point to its center and inserted into its circular list; then, finding a respective suitable starting position in there circular lists, compare the distances between target shape and collation shape from their own starting point, if all distance differences are less than the setting threshold, and the color difference of the two irregular shapes is also less than setting threshold, two irregular shape similar; otherwise they are not similar.

Suitable starting position mentioned above means selecting the appropriate distance differences from the two circular lists to calculate starting position. Following two irregular shape A and B, B is A clockwise rotation of 30°.



A. the original shape



B. A clockwise rotation of 30°

Fig.1 shape and rotation

In figure 1, θ is the angle of the boundary point P in A. When A is rotated 30° clockwise, the boundary point P becomes into P' in the image B, θ becomes θ'. We selected a boundary point (point P) in the original shape (such as A) as the starting point, we must also find the corresponding point (point P in B, rather than point P') from the rotation shape (such as B) to compute the distance during a similar comparison. Otherwise, the comparison does not make any sense because their positions don't correspond.

When determining the corresponding relationship of the boundary points in the two shapes, the similar comparison method of irregular shape can be described as:

(1) Express the irregular shape according the expression method of irregular shape as follows:

$$I = \{F(X_0, Y_0), f(x_0, y_0), E, C\} \quad (6)$$

(2) Records boundary points of the two irregular shapes. Calculate the distance r_i of boundary point A_i in the pattern A sequentially in the direction of from 0 to 360°, and inserted into the circular list $L_A = \{r_1, r_2, \ldots, r_n\}$, n is the number of boundary points of A. In the same way, computing circular list $L_B = \{R_1, R_2 \ldots, R_N\}$, N is the number of the boundary points of B.

(3) Calculate corresponding boundary points of A and B according to the above steps. Assuming A_i is the corresponding to B_j.

(4) Compute r_i/R_j, r_{i+1}/R_{j+1}, r_{i+2}/R_{j+2}, …, r_n/R_N, …, r_1/R_1, if each ratio is less than the set threshold, then the two irregular shapes are similar; otherwise, they are not similar.

The improved similar comparison method of irregular shapes makes the result independent with the changes in rotation, size, pan, etc. It plays a significant role in improving the accuracy of the image search.

III. ANALYZING ALGORITHM PERFORMANCE

The main performance indicators of an algorithm are recall rate and precision. The recall rate reflects the ability of the system to match similar images; precision reflects the ability of the system to deny images which is not similar.

This paper experiments in the Windows operating platform and Matlab7.1 simulation tools, with the test image library Corel, respectively select 100 landscapes, flowers, animals, cars and other theme-based images.

Let P is the image set related to the comparing image in image library, Q is a collection of matched images according to the matching criteria, and p is the number of images in the results related to the comparing image, q is the number of images in the results unrelated to the comparing image, r is the number of images which is related to the comparing image and not be matched in the image library, s is the number of images which is not related to the comparing image and not be matched in the image library. The recall rate (A) and precision (B) can be calculated as follows:

$$\begin{cases} A = P(Q \mid P) = \dfrac{P(P \cap Q)}{P(Q)} = \dfrac{p}{p+r} \\ B = P(P \mid Q) = \dfrac{P(P \cap Q)}{P(P)} = \dfrac{p}{p+q} \end{cases} \quad (7)$$

To explain the effectiveness of the algorithm proposed in this paper, we compared it with the histogram method, and 5 × 5 sub-block histogram feature extraction algorithm [7]. Experiments to select the same type of image from the image library, for each match, calculate the recall rates and its precision, the experimental results shown in Table 1.

Table 1 matching algorithm precision

Recall rate	precision		
	histogram	5 × 5 sub-block histogram	the algorithm proposed
0.1	0.688	0.746	0.863
0.2	0.453	0.605	0.727
0.3	0.402	0.528	0.619
0.4	0.323	0.415	0.522
0.5	0.225	0.342	0.441
0.6	0.208	0.295	0.386
0.7	0.159	0.237	0.303
0.8	0.144	0.183	0.249
0.9	0.122	0.145	0.182
1.0	0.105	0.122	0.167

It can be seen from Table 1, the precision and recall rate of the proposed matching algorithm are higher than the histogram method and 5 × 5 sub-block histogram method. According to the statistics in Table 1, a line chart can be generated shown in Figure 2.

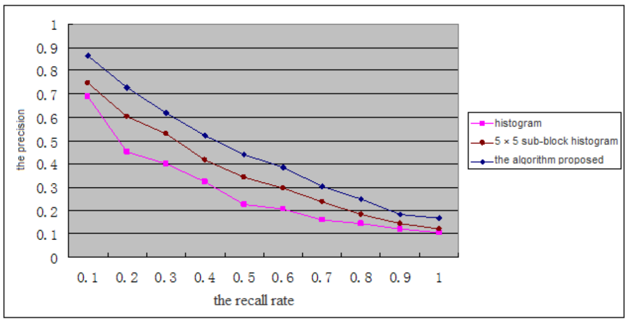


Fig.2 the results of a variety of algorithms

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