The Extraction Of Circle Contour Based On Improved Boundary Tracing Algorithm

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***Abstract*—According to the property of circle contour, analysis the disappointment of circle contour extraction by traditional boundary tracing algorithm, especially under the condition of there is break in contour, an improved boundary tracing algorithm to extract the circle contour is proposed. Based on the break in circle contour, the confirmation method of boundary starting point and the end command of the algorithm are prescribed; According to the property of circle contour and inside branch, the new tracing principle is prescribed. The experiment shows that this method, which can extract the circle contour effectively and quickly, have a good ability of anti-disturbance to inside branch and false boundary.**

Keywords- circle contour; boundary tracing; boundary starting point; eight neighborhood; tracing principle

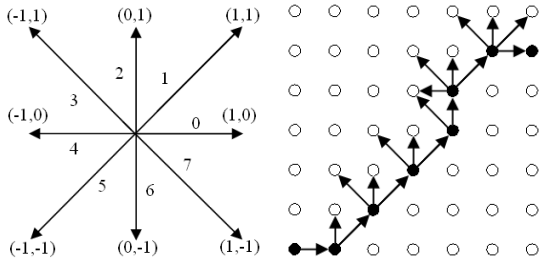
I. INTRODUCTION

In the image processing and analyzing, a lot of important information is contained in the boundary. Whether the boundary outline can be extracted efficiently or accurately has a great effect on the follow-up describing, analyzing and comprehending of the target character. Moreover, the extraction of circle contour plays an important part in the practical application.

Boundary tracing is an important extraction algorithm of boundary outline [1-2]. According to the traditional boundary tracing algorithm (TBTA), as in [3], Junwei Tian has put forward the boundary tracing method based on the estimation direction, it has been realized that more targets can be traced efficiently; Shuang Shi has proposed a new algorithm for boundary tracing of dual layer boundary region growing [4]. In [5], Hai'ou Hu has proposed a smooth curve segment extracting method guided by gradient direction of boundary point. In addition, An ultra-fast user-steered image segmentation paradigm: live wire on the fly proposed by Falcao A X [6], the reptile method proposed by Fusheng Wang [7], A reptile method with memory and alterable window for boundary tracing proposed by Yu Wang [8]. The general boundary can be traced and detected accurately by these algorithms, but for the detection of circle contour, the judgment of non-boundary points is redundant, and the recognition of inside branch or the removal of fake boundary cannot meet the requirements. Thus, according to the image character of circle contour, a new method of circle contour extraction based on improved boundary tracing algorithm (IBTA) has been put forward.

II. TRADITIONAL BOUNDARY TRACING ALGORITHM

Firstly, it is needed to make sure the initial starting tracing point (STP). The image is read orderly from left to right, from bottom to top. Thus, the initial STP is determined and recorded from the lower left region of image. As shown in figure 1(a), a central pixel has eight tracing directions. The initial tracing direction of the STP is set to right (direction 0), then the value of tracing pixel is judged. If it is 0, save the original STP, the current pixel is set as the new STP, the tracing direction is rotated 90 degrees counter clockwise based on the original tracing direction (direction 2) as new one. If the value of point in this direction is not 0, then rotate 45 degrees clockwise based on this direction, judge the value of this pixel again. Keep repeating the above-mentioned course, looking for new boundary point, saving the detected boundary point, as the tracing example shown in figure 1(b), the algorithm ends as the testing point getting back to the original STP.



(a) 8 directions and these offset (b) boundary tracing example

Figure 1. The tracing sketch map of TBTA.

The following problems exist in circle contour extraction by TBTA: 1, if there exists gap below of the contour, the internal point is easily selected as the STP; 2, if there is internal branch, it will be traced by TBTA also; 3, in the tracing of circle contour, the judgment of non-boundary points is redundant, it wastes tracing time; 4, the TBTA ends as the detected point getting back to the initial STP. If there is gap in the boundary contour, the detected points will be traced again until the initial point founded.

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III. IMPROVED BOUNDARY TRACING ALGORITHM

According to the disappointment application of TBTA in circle contour extraction, the TBTA is improved as following: after selecting the determination method of the seed point, it will be ensured on the boundary contour, tracing internal points will be avoided; the boundary tracing principle is improved, internal branches will be avoided tracing, the judgment of non-boundary points will be reduced in the process of tracing, namely, the tracing time will be saved; Under the condition of boundary discontinuousness, the tracing principle will be changed or the algorithm will be ended by judging interrupted point, unlike TBTA, tracing the detected points again will be avoided.

A. The Selection of the Initial Boundary Point

The maximum and minimum values of the respective X, Y component are got by scanning the binary image, namely $x_{\max}$, $x_{\min}$, $y_{\max}$, $y_{\min}$. On the same component, the difference is got from the maximum subtracted the minimum, such as type (1):

$$\begin{aligned} d_x &= x_{\max} - x_{\min} \\ d_y &= y_{\max} - y_{\min} \end{aligned} \tag{1}$$

As diameter corresponds to the longest string in circle, make comparison of the two difference values, the coordinates of points, which corresponding to the bigger difference direction are on the circle contour. Thus, the selecting principles of STP are as following: Under the condition of $d_y \geq d_x$, the STP is selected traditionally. If $dy < dx$, the binary image is scanned from top to bottom, from right to left orderly, so the seed point is determined.

B. Tracing Principle of Circle Contour

In the binary image, boundary exists in the form of coordinate, it has 8 directions as figure 1(a) shown. Thus, for the round boundary, the difference between the current tracing angle and the last one cannot exceed 45 degrees, as figure 2(a) shown, namely as the direction of last direction number or the near direction numbers. Based on above, the principles of improved round boundary tracing are as following:

Under the condition of $d_y \geq d_x$, the STP is got as the chapter2.1. The initial direction is set to right, trace and judge the next point clockwise, if the value of next pixel is 0, the initial STP is saved, conduct the current point as new STP, the tracing direction is rotated 45 degrees clockwise based on the original direction. If it is not 0, the tracing direction is rotated 45 degrees contrary clockwise instead, the value of the current pixel is judged afterward. Repeat the above-mentioned course, keep looking for the new boundary point, save the detected one, it is ended as the detecting point getting back to the initial STP. Figure 2(b) shows the example of boundary tracing, contrasted with figure 1(b), the judgment of non-boundary points has been reduced by IBTA to some extent.

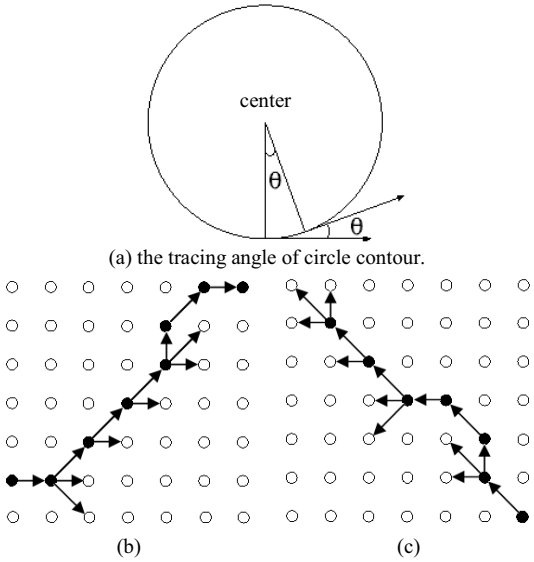


Figure 2. The sketch map of tracing angle and improved tracing principle: (b) counter clockwise boundary tracing example; (c) clockwise boundary tracing example.

For the discontinuous boundary, until the black pixel cannot be found in the three detecting directions, the initial STP is returned, set the initial direction to the left, trace clockwise, estimate the next detected point. If the value is 0, set the current point as the new STP, the tracing direction is rotated 45 degrees contrary clockwise based on initial one. If the value is not 0, rotate 45 degrees clockwise based on the initial tracing direction, estimate the value of the pixel again. Repeat the above-mentioned course until there is no black point founded in the three detecting directions, as shown in figure 2(c).

Under the condition of $dy < dx$, the STP is determined in the top right of the image as step 2.1. The initial direction is set to up, keep tracing boundary by order of counter clockwise until there is no boundary point founded in the three directions. Return to the initial boundary point, set the tracing direction to down, the discontinuous boundary is got by tracing boundary points clockwise.

C. Algorithm Description

The steps of IBTA are described as following:

(1) The maximum and minimum of component X,Y are got by sequentially searched in the binary image, compare the difference of each component, which is calculated by the formula(1), if $d_y \geq d_x$, transfer to step(2); if $dy < dx$, turn to step(3).

(2) The STP is the first pixel of value 0, which is got by sequentially scanning in the image from left to right, from bottom to top. It is in left bottom of the image, recorded as P_0 , deposited in the boundary points group (BPG), preset direction number $k = 0$. Transfer to step (4).

(3) The STP is the first pixel of value 0, which is got by sequentially scanning in the image from top to bottom, from

right to left. It is in right up of the image, recorded as P_0, deposited in the BPG, preset direction number $k = 2$.

(4) Estimate the value of next boundary point in the direction $dir[k]$ from the STP P_0. If the value is 0, it is a boundary point, deposited in the BPG, set the searching direction number threshold $T = (k+1) \bmod 8$ (modulo 8 as direction number), $k = (k-1) \bmod 8$ is set. Keep searching for boundary points in direction $dir[k]$ from this point as the STP. Otherwise, $k = (k+1) \bmod 8$, search the point in direction $dir[k]$, the cycle ends as $k = T$.

(5) If the next boundary point $P_k \neq P_0$ is detected, transfer to step (4); If $P_k = P_0$, namely, the detected point get back to the STP, the boundary tracing algorithm is end, all the boundary point coordinates are stored in the BPG.

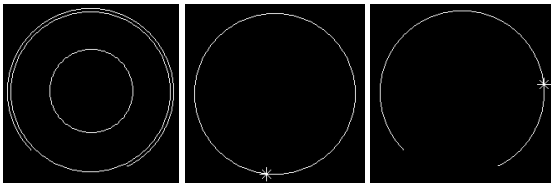
(6) If there is no boundary point founded in all of the searching directions, it indicates that the boundary is intermittent, get back to P_0, search in the opposite direction, and set the initial search direction number $k = (k+4) \bmod 8$.

(7) Set P_0 as STP, the value of next pixel is estimated in the direction $dir[k]$. It is a boundary point if the value of the pixel is 0, deposited in the BPG, set the searching direction threshold $T = (k-1) \bmod 8$, and set the searching direction $k = (k+1) \bmod 8$, keep searching for boundary points in the direction $dir[k]$ from this STP. Otherwise, $k = (k-1) \bmod 8$, search points in direction $dir[k]$, the circulation ends as $k = T$.

(8) If the boundary point is traced, transfer to the step (7). If there is no boundary point traced in searching directions, the boundary tracing algorithm is ended, the coordinates are deposited in the BPG, with the circle contour is extracted.

IV. RESULTS AND ANALYSIS

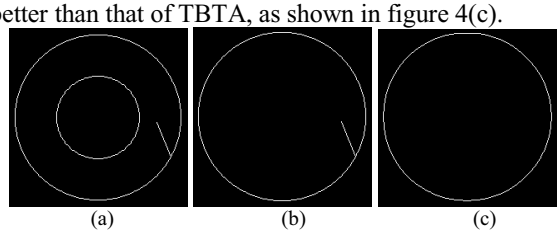
The contrast effects of two methods in tracing the boundary under the case of discontinuous circle contour are shown in figure 3. The figure 3(a) shows the circle contour with gap in bottom, by TBTA, the STP is selected from left to right, from bottom to top. The STP is selected on the inner circle contour with the location of left bottom, the tracing result is inner circle contour instead of outer circle contour, as shown in figure 3(b), "*" represents the location of boundary STP; By the IBTA, the selection principle of STP is ensured according to step (1), under the condition of figure 3(a), the selection principle of STP is from top to bottom, from right to left, the STP is selected on the outer circle contour, which is selected as figure 3(c) shown.



(a) (b) (c)

Figure 3. The contrastive effect of contour with gap below by two methods: (a) circle contour with gap bellow; (b) the effect of (a) by TBTA; (c) the effect of (a) by IBTA.

The contour with inner branch are extracted by two methods, the contrastive effects are shown in figure 4. The inner branch will be extracted as contour also by TBTA, as figure 4(b) shows; While, by IBTA, the contour will be extracted without the disturbance of inner branch, the effect is better than that of TBTA, as shown in figure 4(c).

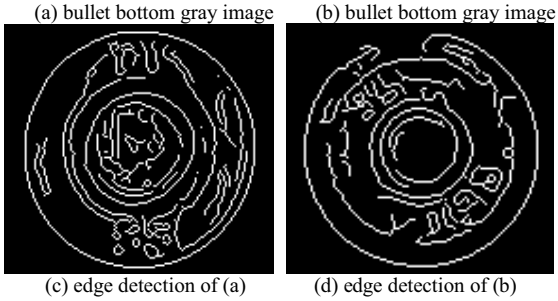


(a) (b) (c)

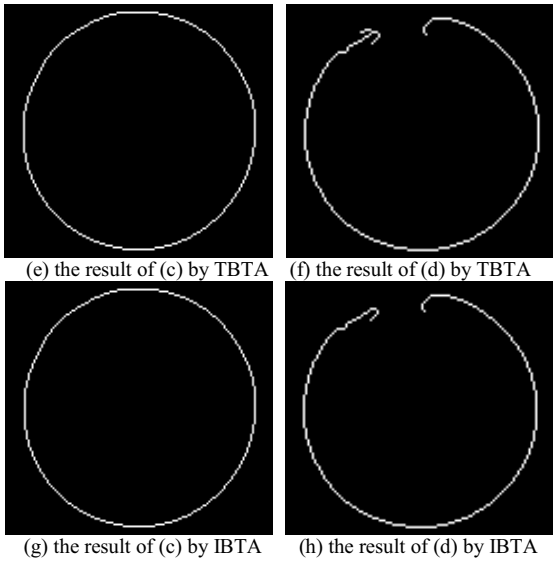
Figure 4. The contrastive effect of contour with inner branch by two methods: (a) contour with inner branch; (b) the effect of (a) by TBTA; (c) the effect of (a) by IBTA.

The contrastive extraction effects of bullet bottom circle contour by two methods are shown in figure 5 (a) and (b) figures show the gray image of bullet bottom, (c) and (d) figures respectively correspond the application of edge detection by Canny operator [9] in (a) and (b) figures. As (c) and (d) figures show, owing to the influence of lettering and texture, there are many lines without rules in bullet bottom, easily connected to the outer circle contour, the phenomenon of inner branch as described above will occur. At the same time, due to the impact of uneven illumination in figure (b), there are discontinuity and pseudo-edge at the discontinuity point in figure (d) corresponding to the effect of edge detect.

(a) bullet bottom gray image (b) bullet bottom gray image



(c) edge detection of (a) (d) edge detection of (b)



(e) the result of (c) by TBTA (f) the result of (d) by TBTA

(g) the result of (c) by IBTA (h) the result of (d) by IBTA

Figure 5. The contrastive application effect of bullet bottom circle contour extraction by two methods

Apply two methods in detecting the whole bullet bottom circle contour of figure 5(c), figure 5(e) and (g) correspond to the detecting result of TBTA and IBTA respectively, two tracing methods are the same in the number of tracing points. Because of the judgment of non-boundary points is reduced, the IBTA is 25.1% faster than TBTA; For the detection of intermittent circle contour in figure 5(d), the result of TBTA is shown in figure 5(f), the number of traced points is 449. The result of IBTA is shown in figure 5(h), 285 traced points. The IBTA is 31.7% faster than TBTA. The specific tracing parameters of bullet bottom circle contour by two methods are shown in table 1:

TABLE I. THE CONTRASTIVE TRACING PARAMETERS OF BULLET BOTTOM CIRCLE CONTOUR BY TWO METHODS

Tracing goal	Method	No. of tracing points	Time/ms
Whole circle contour	TBTA	350	0.463
	IBTA	350	0.347
Discontinuous circle contour	TBTA	449	0.363
	IBTA	285	0.248

For the tracing of intermittent circular contour, the IBTA is less in number, shorter in time than the TBTA, the reasons are as following: (1) the judgment of non-boundary points is reduced in the tracing process; (2) the algorithm is ended until no boundary points can be founded in the tracing direction, the detected boundary points are avoided to be traced again, unlike the TBTA by looking for the STP to end the algorithm.

It is can be seen from the comparison of figure 3(f) and 3(h) also, the pseudo circle contour, which are changing radius arcs, cannot be effectively identified and removed, it is the place where the proposed method should to be further improved and perfected.

V. CONCLUSION

According to the image character of circle contour, a new method of circle contour extraction is proposed based on IBTA. The experiment shows that this method, which can extract the circle contour effectively, have a good ability of anti-disturbance to inside branch and false boundary, put up a good ability of real time and robustness. This method achieves fine effect in the application of circle contour extraction, and it is also applicable to circle contour extraction of other round objects.

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