Multi circle detection by using evidence accumulation

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Abstract

The traditional circle detection algorithm has complex computation, large memory space occupation and other deficiencies. It has low detecting efficiency and not suitable for the multi circle detection. So it proposes a multi circle detection method based on global search and evidence accumulation in the paper. The evidence accumulation and the weighted average are combined in the algorithm. The pseudo centre processed during the evidence accumulation are classified and analysed. Three kinds of pseudo centres are eliminated by class. Finally, the other circle parameters are calculated. It is proved that the algorithm has high precision, high efficiency, and low sensitivity to the defect of local information. Also the detecting time will not increase with the number of circles. The multi circle detection effect is obviously superior to the traditional randomized circle detection algorithm.

Keywords: Multi Circle Detection, Global Search, Evidence Accumulation

1 Introduction

Circle is one of the basic geometries in image analysis. The relevant information of the circles in image is required to rapidly detect in many fields, such as quickly detecting the location and size of round holes in the part, detecting round PCB printing plate in industry and so forth. Therefore, the circle detection has special significance in image analysis, pattern recognition and computer vision [1, 2].

The methods such as standard Hough transform (SHT) are commonly used to detect the circles [3]. It needs complex computation and large memory space, on account of using "one to many" mapping. Also it is not good at multi circle detecting. In recent years, the domestic and foreign scholars have done some researches in multi circle detection methods [4]. Xu presented randomized Hough transform (RHT), which took "many to one" mapping [5, 6]. It avoided huge amount of calculation comparing to SHT. But the sampling without targets could cause a large number of invalid samplings and invalid accumulations. So the performance of the algorithm was reduced. In addition, Chen proposed a randomized circle detection algorithm (RCD) not in RHT series [7]. The detecting speed was faster than RHT in the case of below medium noise ratio.

RCD detection algorithm and Hough transform have many problems in practical application. The probability of invalid sampling is great in multi circle detection. And the efficiency of the algorithm is low, because there are many square and square root operations in it. The test results have greater offset, because the threshold parameters have been set are different in both algorithms. The detecting speed will suffer great interference when the circle is incomplete, the image has large disturbances and so on. Therefore, a circle detection method based on global search is proposed. The evidence accumulation and the weighted average are combined in the algorithm. The pseudo centre processed during the evidence accumulation are classified and analysed. Three kinds of pseudo centres are eliminated by class. Finally, the other circle parameters are calculated.

2 Algorithm principle

2.1 GLOBAL SEARCHING CENTRE COORDINATE

Please see Figure 1. Suppose that the image size is M pixel× N pixel. After edge detection, there is

$$I(x,y)=\begin{cases}255, & if\\ 0, & else\end{cases}, \qquad (1)$$

where $I(x,y)$ $(0\le x<M, 0\le y<N)$ is the grey value of row x the column y in the image.

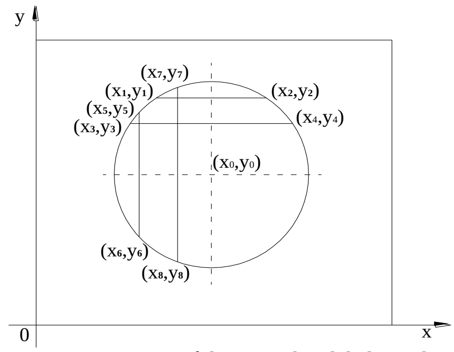

FIGURE 1 Diagram of the centre by global searching

Two arrays a_{2M} and b_{2N} are created. The position of each element in the array corresponds to the pixel coordinate of the centre. The size of the element stored in

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the array is namely the evidence accumulation value of the corresponding pixel becoming the centre. Searching the coordinates of the centre consists of the following steps.

First, the pixels in the first row are searched. The horizontal ordinate average of each edge pixel and its nearest edge pixel is calculated successively. The value $a[2\times p_x]$ in the array a_{2M} will be added 1 after calculating one average value p_x each time. Then the pixels in each column will be processed as the above steps. The value $b[2\times p_y]$ in the array b_{2N} will be added 1 after calculating one average value p_y each time. See Equation (2).

$$\begin{cases} a[i]=a[i]+1 \quad if \quad i_1+i_2=i \\ b[j]=b[j]+1 \quad if \quad j_1+j_2=j \end{cases}. \tag{2}$$

In Equation (2), i_1, i_2 are the horizontal ordinates of the two adjacent pixels; j_1, j_2 are the vertical ordinates of the two adjacent pixels; and i, j is the position of the corresponding array element.

After completing global searching, the threshold T is set. The values in two arrays will be respectively compared with the threshold *T*. The position of the element which is greater than T in the array a_{2M} is twice of the centre abscissa value. And the position of the element which is greater than T in the array b_{2N} is twice of the centre ordinate value.

The evidence accumulation value in the array reflects the probability of each coordinate value taken as the centre coordinate, because of the symmetry of the circle. Since the accumulation value is gotten from calculating the average of the adjacent pixels, it has high degree of distinction, and the other kinds of edge interference can be effectively removed.

2.2 CHARACTERISTIC ANALYSIS OF PSEUDO CENTRE

For the multi circles detection, a variety of pseudo centres will be emerged after completing evidence accumulation. Because the digital image is in single pixel, the evidence accumulation values of the two adjacent coordinates in one circle are both greater than the set threshold, and they are not much difference. So the pseudo centre is produced. Please see Figure 2.

Pseudo centre can be divided into three categories:

1) Type 1 pseudo centre. Because the abscissa and ordinate values obtained from the evidence accumulation have many different combinations, as well as the adjacent coordinate probably can generate pseudo centre, one horizontal coordinate value can correspond multiple possible vertical coordinate values. The resulting multiple pseudo centres such as A C, E, F, G, H are shown in Figure 2.

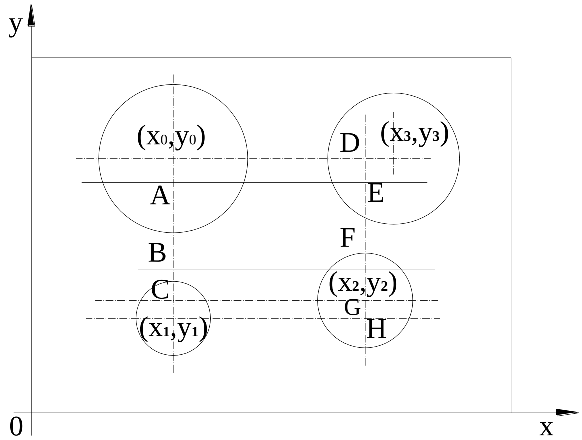


FIGURE 2 Diagram of pseudo centre

2) Type 2 pseudo centre. There will be a vertical coordinate value having larger evidence accumulation value between the two circles, if the centre horizontal coordinate values of the two circles are equal. This point is obtained from the evidence accumulation of the lower edge in the above circle and the upper edge in the below circle. Similarly, there will be a horizontal coordinate value having larger evidence accumulation value between the two circles, if the centre vertical coordinate values of the two circles are equal. Point B is this type of pseudo circle. Please see Figure 2.

3) Type 3 pseudo centre. The circles corresponding to (x_2, y_2) and (x_3, y_3) are shown in Figure 2. If the range of the two circles has larger overlap in the abscissa, the evidence accumulation values of (x_2, y_2) and (x_2, y_3) are both large, when doing evidence accumulation along the y axis for the edge points near x_2 and x_3. x_3 has the same situation. Also, the similar situation will also appear, if the range of the two circles has larger overlap in the ordinate. Point D is this type of pseudo circle. Please see Figure 2.

For type 1 pseudo centre, the vertical coordinate value corresponding to each horizontal coordinate can be found, only to do evidence accumulation for the edge points nearby every possible horizontal coordinate value along the vertical coordinate.

However, type 2 pseudo centre is not in the circle. The edge points nearby every possible horizontal coordinate value along the vertical coordinate are scanned. So the vertical coordinate of the edge point when doing evidence accumulation to the vertical coordinate of type 2 pseudo centre must vary greater, the further it is from the horizontal coordinate value. Type 2 pseudo centre can be eliminated according to this characteristic.

The vertical coordinate of type 3 pseudo centre (such as point D in Figure 2) is scanned. The difference of the edge points is great, when doing evidence accumulation to the vertical coordinate of point D on both sides of x_2. So, type 3 pseudo centre can be eliminated.

2.3 ELIMINATING PSEUDO CENTRE

According to the analysis in Section 2.2, all kinds of pseudo centre will be respectively eliminated.

1) Eliminating the adjacent centre and type 1 pseudo centre

The adjacent coordinate points have been found out by scanning the horizontal and vertical coordinates. The larger point of the evidence accumulation values is selected. If the difference between them is very small, the average of two points is taken as the centre coordinate. Setting thresholds t_1 and t_2, and the pixels of $2t_1+1$ columns from column (x_0-t_1) to column (x_0+t_1) are selected. The pixels per column are processed according to the method in section 2.1.

$$b[j]=b[j]+1, \tag{3}$$

if $j_1+j_2=j$ and $(x_0-t_1)\le i_0\le(x_0+t_1)$, where j_1 and j_2 are the vertical coordinate values of the nearest edge point in column i_0, and $b[j]$ is the evidence accumulation value for the vertical coordinate j. The vertical coordinates whose evidence accumulation value is greater than the threshold t_2 are the probable vertical coordinates $y_0^{'},y_1^{'}\cdots$ corresponding to x_0. The vertical coordinate values of the edge points among the possible vertical coordinate values are recorded. Six pseudo centres including A, C, E, F, G, H can be eliminated, after x_0, x_1, x_2 have been processed in order.

2) Eliminating type 2 pseudo centre

The edge points carried out the evidence accumulation to the longitudinal coordinate $y_0^{'}$ are gathered in point group $C_{y_0^{'}}$. The maximum longitudinal coordinate point in column (x_0-t_1) or column (x_0+t_1) among the point group is chosen. If the ordinate of the point is larger than that of the maximum ordinate point in column x_0, it is the pseudo centre. The pseudo centre B can be eliminated, after x_0, x_1, x_2 have been processed in order.

3) Eliminating type 3 pseudo centre

In point group $C_{y_0^{'}}$, the longitudinal coordinate value which is greater than $y_0^{'}$ subtracts the one less than $y_0^{'}$ from column (x_0+1) to column (x_0+t_1), and the subtraction result is added up. Accordingly, the longitudinal coordinate value, which is greater than $y_0^{'}$ subtracts the one less than $y_0^{'}$ from column (x_0-t_1) to column (x_0-1), and the subtraction result is added up. Finally, the two calculated sums are subtracted.

$$\delta_0=\sum_{x_0+1}^{x_0+t_1}(y_i-y_j)-\sum_{x_0-t_1}^{x_0-1}(y_k-y_l). \quad (y_i,y_j,y_k,y_l\in C_{y_0^{'}}) \tag{4}$$

In equation (4) y_i is the ordinate value greater than $y_0^{'}$ from column (x_0+1) to column (x_0+t_1) in point group $C_{y_0^{'}}$, and y_j is the ordinate value less than $y_0^{'}$. y_k is the ordinate value greater than $y_0^{'}$ from column (x_0-t_1) to column (x_0-1) in point group $C_{y_0^{'}}$, and y_l is the ordinate value less than $y_0^{'}$. All possible ordinate values are calculated in turn by using equation (4). The corresponding differences having been gotten are $\delta_0,\delta_1,\cdots$. The threshold ε is set. The point whose difference δ is greater than the threshold ε will be eliminated. The pseudo centre D can be eliminated, after x_0, x_1, x_2 have been processed respectively.

So far, the pseudo centres corresponding to the abscissa x_0, x_1, and x_2 have been all eliminated. Similarly, the abscissa x_3 and the ordinate values $y_0,y_1\cdots$ can be processed as the above. The centre coordinates corresponding to it can be found. Finally, the evidence accumulation values of the true centre and its 8 adjacent points are taken as the weight. The coordinate values are carried out the weighted average, and the centre coordinates are gotten.

2.4 CALCULATING THE RADIUS

The images often have all kinds of noises in the actual industry detecting. In order to avoid noise interference, cluster analysis and the weighted average are used to minimize the error. The distance L from each edge pixel to the detected centre is calculated. The pixels close to the distance L are gathered as a class. Then the threshold ξ is set, the point group $C_{\max}$ gathered most points in the range of 2ξ is selected. The equation for calculating the weighted average of the radius is as follow. Please see Equation 5.

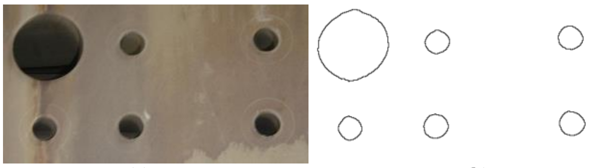
$$\sum_{L_n\in C_{\max}}\frac{P_n}{P_{sum}}L_n=L, \tag{5}$$

where L_n is the distance between the edge point and the centre in class $C_{\max}$. P_{sum} is the total number of points in class $C_{\max}$. P_n is the number of edge points whose distance is L_n in class $C_{\max}$. The value L calculated by equation (5) is the radius.

The clustering method can give full play to the effect of the evidence accumulation. The result can effectively avoid deviating from the correct value. The weighted average method used to calculate the radius can reduce the inherent pixel error in digital image, and improve the reliability and accuracy of detection.

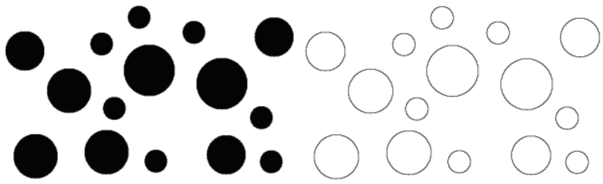
3 Experiment results and analysis

Please see Figure 3 (a) and Figure 4 (a). The sizes of the two experimental images are both 280pixel×166 pixel. First, an array $a[560]$ and $b[332]$ are created and initialized, and the parameter values $T=4$, $\varepsilon=2$, $\xi=0.5$, $t_1=4$ and $t_2=5$ are set. The proposed algorithm in the paper is used to separately detect the circles in two images. Please see Figure 3 (b) and Figure 4 (b).Then RCD algorithm is used to separately detect the circles in two images. The above two detections are carried out in the same hardware experiment environment.



(a) (b)

FIGURE 3(a) Automobile part image. (b) Proposed algorithm multi circle detecting result



(a) (b)

FIGURE 4(a) Experimental image. (b) Proposed algorithm multi circle detecting result

The comparisons of detected value and real value of Figure 3(a) are shown in Table 1.The error between the test results by the proposed algorithm and the real value is less than one pixel. Its accuracy is obviously superior to the RCD method. Please see Table 2. When the number of the circles increases, the executing time of RCD algorithm obviously increases. However, the executing time of the proposed algorithm is almost unchanged.

TABLE 1 Comparison of detected value and real value of Figure 3(a) (Unit: pixel)

Circle number (centre, radius)	**1**	**2**
Proposed algorithm	(41.8,117.9,33.7)	(38.9, 35.3,11.5)
RCD	(42.7,118.5,32.9)	(40.2, 35.8,12.7)
Real value	(42,118,34)	(39, 35,12)
Circle number (centre, radius)	**3**	**4**
Proposed algorithm	(118.4,37.3,12.1)	(119.7,121.2,11.7)
RCD	(120.3,36.4,10.8)	(120.5,122.6,12.9)
Real value	(119,37,12)	(119,122,12)
Circle number (centre, radius)	**5**	**6**
Proposed algorithm	(243.1,125.5,11.9)	(244.5,40.1,12.1)
RCD	(245.3,124.1,11.7)	(243.7,38.8,11.3)
Real value	(244,125,12)	(244,40,12)

TABLE 2 Comparison of executing time between the proposed algorithm and RCD algorithm (Unit: ms)

Images	Figure 3(a)	Figure 4(a)
Proposed algorithm	78	85
RCD	356	1054

4 Conclusion

The experiment and analysis showed that the proposed algorithm had better performance than the traditional circle detection algorithm. First, it avoids the shortcoming of largely invalid random sampling probability in RHT and RCD algorithms, because the proposed algorithm applied the global search to the image. Secondly, it used the simple averaging operation instead of the square and square root operations in the traditional algorithm, and increased the efficiency of the algorithm. Again, it adopted the evidence accumulation combining with the weighted average to calculate the parameters of the circle, and improved the stability and accuracy of the results. It is proved, that the proposed algorithm had fast detection speed, high precision, and great practical value after detecting multiple images.

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