A new boundary tracing algorithm of the contour of objects in the binary image

Leiming Sun, Tianshun Huang

Henan polytechnic, Zhengzhou, 450046, China

Corresponding author's e-mail: huangthhp@163.com

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Abstract

By analysis of common boundary tracing algorithm in the binary image identification, this paper proposes a universal boundary tracing algorithm based on contour, which can judge the trend of contour according to the last boundary point. In search for the next boundary point, it only needs to judge 5 points on the candidate and then the next boundary point can be found. Thus the method reduces search times and the boundary tracking is greatly reduced. The algorithm is also effective for line segment whose contour is not closed by scanning the contour to get information. Experiments show that the algorithm is not only fast, but also accurate about the contour recognition. For the object which has complex images, algorithm can embody its superiority.

Keywords: image recognition, binary image, boundary tracing, contour of target objects, pattern recognition

1 Introduction

In the field of pattern recognition, shape feature of the image is an important index for feature extraction, in many cases, only by knowing shape feature of the image can we make the further analysis of the image quantitatively. And to determine the boundary contour is a prerequisite for study of shape feature, which is also the premise of computer automatic image recognition. The recognition of the boundary contour has a significant effect on the description, identifying and understanding of the feature.

Machine vision is widely used in modern mechanical systems, such as semiconductor end-package equipments, surface mounting machines and mobile robots et al. But the images acquired by the CCD camera in these equipments are generally influenced by such factors as vibration of the mechanical structure, quality and resolution of cameras and illumination variations et al. These disadvantageous factors usually will lead to the fuzziness of the images and make it difficult to realize the accurate edge detection of the blurry images.

To extract the edges from the images, derivative edge detection operators, such as Sobel operator, Roberts operator and Laplacian operator et al., are commonly used. These operators are computationally simple while they can't extract edge information from the blurry images satisfactorily [1]. The traditional fuzzy edge detection (TFED) algorithm introduces the fuzzy enhancement method and is suitable for edge detection of some blurry images [2-3]. The algorithm first enhances the image by means of mapping transformation, fuzzy enhancement operator and inverse mapping transformation and then extracts the edge information from the enhanced image using 'min' or 'max' operator. This algorithm is computationally complex because the mapping transformation involves the exponential calculation and it will lead to the loss of pixels with low gray value. In addition, the "min" or "max" operator has a relatively lower edge positioning accuracy in extracting edges from the images.

Boundary tracking is an image segmentation method based on gradient. Starting from a boundary point in the gradient map, we can determine a new boundary points, based on a previous boundary point. Traditional boundary tracking methods include the worm following method, raster scan method and T algorithm and so on. But these methods must be repeated many times to get results, and sometimes it may also repeat following the same local area, which causes the program into a loop. Target neighborhood point of boundary tracking method evolves from the worm following method, which overcomes the shortcomings of worm following method. With the method, a cycle can accurately get the contours of objects and the experimental effect is good. On this basis, the proposed algorithm in this paper can determine the trend of contour according to the former boundary point position, which can thus reduce the searching times, and improve the searching efficiency. The more complex the target image is, the more likely it is to demonstrate its superiority.

Images are often corrupted by impulse noise in the process of transmission over noisy communication channels or recording by noisy sensors [4]. The median filter has been widely used for removing impulse noise because of its superior performance in noise suppression and edge preservation in comparison with the linear filters [5-6].

2 Traditional boundary tracking methods

A common boundary tracking algorithm is the worm following method, which obeys the following rules. An ideal bug going from white background pixel area to black background pixel area and the black pixel region is represented as a closed contour. As they entered the black pixels, they turn left and continue to the next pixel. If the next pixel is also black, then the worms turn left again. But if a pixel is white, the worms turn to the right. This process continues until the worms reach the original point. This method has the following problems [7]:

(1) Some small convenes may be detoured, as is shown in small convex in right corner in figure. 1. To avoid this problem, we must choose some different starting points and initial directions to repeat the process, and then take the same path as the target contour. The number of repeating times depends on the complexity of the visual images. But even if it repeats for many times, it may not be able to avoid this problem.

(2) The worms may fall into the trap, namely they will repeatedly crawl around a local closed region, and cannot go back to the starting point. To avoid this problem, the worms can be equipped with the memory function, so they can remember the former steps and return to the original road from the incorrect route. Due to the repeated courses, the total step numbers of the worms double that of a single course. Apparently, for some complex image, the calculation is too huge, or even it is impossible to realize. Also it is likely for the worms to have been stuck in the trap in the choice of the starting point, and the misjudgement is made.

Raster scan method is to track the boundary by scanning the rows and lines of the image after setting a certain threshold for many times. The disadvantage of the method is that it needs to keep adjusting the threshold, and the scanning depends heavily on the direction of the raster scanning. Also it requires the repeated combination of row scanning and line scanning. Because the blindness of threshold choice and the uncertainty of the times for row are scanning and line scanning, it is very difficult to find the accurate contour of the target. T (Trace) algorithm in the contour coding can also be used to track the boundary contour line in the region. T algorithm is 4 neighbourhood searching algorithm, whose searching rules are related with the entrance direction. Also its searching efficiency is not high, and cannot overcome effect on the algorithm exerted by the internal hole in the boundary.

As the improvement of traditional algorithm, this paper proposes a new tracking algorithm, which can effectively track the outer boundary and can overcome the influence of the inner boundary on the algorithm. It can also accurately track the closed lines. The principles of algorithm are as follows: the boundary tracking start to scan image point by point from the gradient image in the upper left corner. When the target is met, it track the target in sequence until the tracking follow-up point returns to the starting point (for a closed contour) or there is no new success or follow-up point (for non-closed line). If it is not closed contour, when the tracing is finished on one side, the new tracing should begin from the starting point in the opposite direction until it tracks another point of termination. When there are multiple separated contours, in order to avoid being struck in the dead cycles, the contours should be tracked one by one. The former areas which have been treated well should be filled in by the background colour.

Suppose the grab values in the image are $g_0, g_1, \cdots, g_n$ ($g_0 < g_1 \cdots < g_n$) and for any one grab value g_i $(i = 0, \cdots, n)$ the number of pixels with their gray values equal to g_i is q_i, then the mathematical expectation value of all the gray values can be computed. Because the pixels with gray values equal to 0 have a degrading influence on the computation of the optimal threshold, these pixels should be excluded to produce the appropriate threshold Q.

$$Q = \begin{cases} \dfrac{\sum_{i=1}^{n} g_i q_i}{\sum_{i=1}^{n} q_i} & g_0 = 0 \\ \dfrac{\sum_{i=0}^{n} g_i q_i}{\sum_{i=0}^{n} q_i} & g_0 \neq 0 \end{cases} . \tag{1}$$

Obviously, the threshold Q means the weighted average of non-zero pixel values. Based on the optimal threshold Q, all the pixels in the image can be classified into the two sets, namely, F_O with high gray values and F_B with low gray values. The mean value A_O for the set F_O and A_B for the set F_B can be computed [8].

$$A_O = \frac{\sum_{f_{i,j} \in F_O} f_{i,j}}{S_O}, \tag{2}$$

$$A_B = \frac{\sum_{f_{i,j} \in F_B} f_{i,j}}{S_B}, \tag{3}$$

where S_O and S_B denote the sum of objects pixels and the sum of background ones, respectively.

When the image is changed from the spatial domain into the fuzzy domain, the fuzzy enhancement operator H_r is adopted to realize the function of image enhancement.

$$p'_{i,j} = H_r(p_{i,j}) = H_1(H_{r-1}(p_{i,j})), \tag{4}$$

$$H_1(p_{i,j}) = \begin{cases} \dfrac{p_{i,j}^2}{t} & 0 \le p_{i,j} \le t \\ 1 - \dfrac{(1-p_{i,j})^2}{1-t} & t < p_{i,j} \le 1 \end{cases}, \tag{5}$$

where r denotes the iterative times and it has a great influence on the image enhancement effect. To enhance the image moderately, r is usually chosen as 2 or 3. t denotes the fuzzy characteristic threshold and it can be chosen more flexibly in the FMFE algorithm than the traditional fuzzy enhancement algorithm with t predefined as 0.5 .

As is shown in table 1, if the point (x,y) is a boundary point, the next boundary point must be within 8 adjacent domains of the point (x,y). The coordinate representation of 8 pixel position in the adjacent domains and coding representation are shown in table 2. The problems are to determine what rules to follow in order to quickly and effectively search and find the next boundary point in 8 adjacent domains.

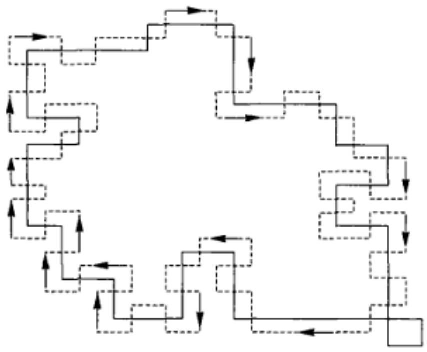

FIGURE 1 Identifying the boundary with "worm"

TABLE I The run time for five edge detection algorithms

(x-1,y-1)	(x-1,y)	(x-1,y+1)
(x,y-1)	(x,y)	(x,y+1)
(x+1,y-1)	(x+1,y)	(x-1,y+1)

TABLE II The run time for five edge detection algorithms

3	2	1
4	P	0
5	6	7

According to the relative position of the former point and the current point, we can roughly determine the boundary trend. Therefore in search of the next point, there is no need of calculate and compare the 8 adjacent domains of the current point. But according to position's difference between the previous point P and the current point C (a total of 8 possible directions), the next point can be tracked by calculating and comparing the 5 pixels in the edge direction, which will greatly reduce the amount of calculation is quite.

So the principles of searching for the next boundary point are as follows: set N as position coding of the current point P (x, y) at 8 adjacent areas of the previous boundary point C. from the position coding N, the position where the current point (x, y) in 8 adjacent areas moves clockwise 2 pixels is the position where the new searching for the next boundary point starts. If it is not boundary point, then from the starting point of the search, searching in counter clockwise direction sequentially for 5 times that can really find the next boundary point [9-10].

For example: see table 2, if the position coding of the current point P in the previous boundary point is 1, then we know that according to the criterion, the starting point of the search is the point whose position code is 7. If it is not the target point, from the beginning point 7, we can sequentially search the points whose position codes are 0, 1, 2, 3 respectively. When the first point appeared in the gray area is equal to the target value, the pixel is the next boundary point needed. The steps of 8 neighborhood boundary tracking algorithm to be implemented are as follows: set the value of background point in the image is 0, the target point is 1, P_k is the kth boundary points, the initial value of k is 0, and t is the number of boundary end points.

(1) Setting value of the interested target area label;

(2) Scanning image from left to right and from top to bottom until discovering the first point whose pixel is 1 and whose value is label. The point is the starting point of the boundary P0, store the coordinate (x, y) in the sequence list of boundary points, and preset t is 0 and the position code is 0;

(3) Determining the starting position of searching the next target according to the above criteria, then from the current position in the counterclockwise direction, check the 8 neighboring pixels of the current boundary point, when the pixel label value is equal to the predetermined tag value for the first time, the pixel is the new boundary point P_k (k=k+1), and record its position coding value in the 8 neighborhood areas;

(4) If the new boundary point P_k = P0, the it returns to the starting point, and the contour tracking finish, the coordinate of the point stored at the boundary point sequence is the external boundary points of the object, then turn to the step (7);

(5) If the new boundary point $P_k \neq P0$, consider P_k as the current point, record its position code, and then turn (3);

(6) If the target point is not found, it indicates that the point is the end point of the contour, and the numbers for the end points is t plus 1. If t=1, set P0 as the current point, whose position code is 4, turn to step (3), if t=2, then you can turn to step (7);

(7) If it needs to track other target contour, turn back to step (2); otherwise, the algorithm terminates. Because this algorithm can memorize the position of current points in the former boundary point, in the search for the next target point, there is no need to search all the points in the 8 neighborhood areas. It only needs to search for 5 times to find the target point, and the intelligent character greatly shortened the time of boundary tracking.

3 Experimental results

Experiments show that by using the method of documenttary, it needs to search the 8 neighbourhood areas respecttively for 4368 times and 9896 times, but by using this algorithm, it only needs to search the 8 neighbourhood areas respectively for 3310 times and 7438 times to accomplish the boundary tracking of the object. The working efficiencies were increased by 24.2% and 24.8%. Therefore, for the target which has complex image, this algorithm can embody its superiority.

All the algorithms programmed in VC++ language are run on the Intel Pentium III computer (CPU: 477MHz; RAM: 120M). For each algorithm, it is implemented for ten times and the average time spent for the ten implementations is used as the run time. The approximate run time of these algorithms used for the chip image and module image is shown in TABLE I. Here it should be noted that the run time excludes the time involved in the binarization of the edge image.

The visual comparisons of loading speed for a same picture using boundary tracing algorithm, GA-FET and AGA-FET is shown in figure 2. In the same consuming time, the AGA-FET loading per cent is more than boundary tracing algorithm, GA-FET. We can notice that the loading per cent does not make linear change to the consuming time.

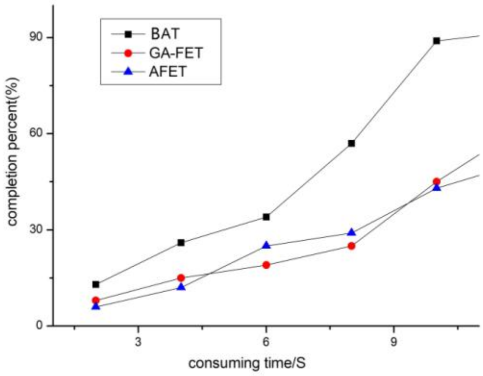

FIGURE 2 Comparisons of loading speed for a same picture using boundary tracing algorithm, GA-FET and AGA-FET

For each algorithm, it is implemented for ten times and the average time spent for the ten implementations is used as the run time. The visual comparisons of impulse noise for a same picture using boundary tracing algorithm, GA-FET and AGA-FET is shown in figure 4. In the same consuming time, the AGA-FET impulse noise is less than boundary tracing algorithm, GA-FET. To restore the highly corrupted image effectively, the adaptive genetic algorithm graphics design based on fuzzy entropy thresholding method (AGA-FET) is proposed in this letter. Different from many well-known decision-based filters, the proposed filter uses the progressive noise detector to identify the corrupted pixels and adopts the adaptive weighted mean filter to remove the detected impulse noises. By combining this novel noise detector with the distinctive mean filter, the adaptive genetic algorithm graphics design based on fuzzy entropy thresholding method (AGA-FET) achieves significantly better restoration performance than many other decision-based filters at the various noise ratios, especially when the image is highly corrupted by impulse noise. The comparison between the run time for the chip image and that for the model image can demonstrate that the advantage of AGA-FED algorithm over other algorithms in the computation efficiency is more obvious with the increasing image size.

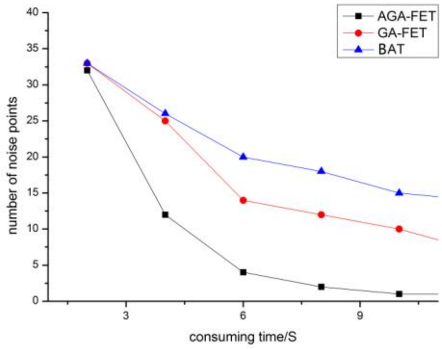

FIGURE 3 Comparisons of impulse noise for a same picture using boundary tracing algorithm, GA-FET and AGA-FET

The visual comparisons of graphic performance indexed by colour saturation for a same picture using B boundary tracing algorithm, GA-FET and AGA-FET is shown in figure 4.

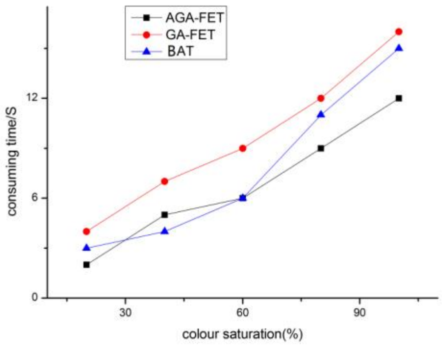

FIGURE 4 Comparisons of colour saturation for a same picture using boundary tracing algorithm, GA-FET and AGA-FET

5 Conclusions

The new algorithm, compared with the traditional boundary tracking algorithm, can scan the information of the target areas' contour for one time. At the same time, according to the method of searching boundary points in the 8 neighbourhood areas, it only needs to search the areas for maximum 5 times to find the target point, which greatly shortened the time of boundary tracking and improve the efficiency of contour tracking. Experiments show that the proposed algorithm in this paper is effective for the boundary tracking of the object in the binary image.

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Authors

Leiming Sun, born in January 14, 1980, Henan of Zhoukou city

Current position, grades: lecturer
University studies: physical electronics
Scientific interest: electronic information engineering technology
Publications : seven
Experience: After graduation from the university to the huawei communication technology corporation in 2006. Transferred to the department of electrical engineering of the henan polytechnic as full-time teacher in 2007

Tianshun Huang, born in June 4, 1963, Henan of Nanyang city

Current position, grades: associate professor
University studies: physics
Scientific interest: architecture electric
Publications: sixteen
Experience: After graduation from the university to the henan water conservancy and hydroelectric power school in 1986.In 2001 transferred to the department of electrical engineering of the henan polytechnic as full-time teacher.