AN OBJECT CONTOUR EXTRACTION USING LOCAL STRUCTURE INFORMATION CAPTURED BY A SPOTLIGHT FILTER

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ABSTRACT

In this study, a spotlight filter for capturing the local structure information in tracing object's contour is proposed for object contour extraction. By searching the possible contour path between the initial source and destination contour points, the spotlight filter is able to capture the local structure information along the path, filter out the edge candidate pixels with weak evidence of being on contour and extract the correct contour. The spotlight filtering can then be operated in parallel on all pairs of initial source and destination contour points of an object to achieve a closed contour of the object. The proposed spotlight filter is tested on a synthetic object image with noise and a real medical image and better results are obtained in terms of accuracy and computational efficiency by comparing with other contour following methods.

***Index Terms*—** spotlight filter, contour extraction, contour tracing

1. INTRODUCTION

Object contour is the major perceptual information in both human and machine vision to segment and recognize large among of different objects [1]. Recently, many contour tracing and edge following methods have been proposed to solve the problem of contour extraction [2-5]. An edge tracing method proposed by Chen et al. [2] was to search for the next boundary point on the eight different directions of edge from a given starting point; however, the method required conventional edge detection for whole image as the first stage. The initial edge point selection (IEPS) proposed by Hsu et al. [3] avoids the first stage calculation of [2], and the set of initial edge points found by IEPS divides the contour into contour segments, which enables the following segmental contour following (SCF) to obtain more accurate contour results.

In this study, a "spotlight filter" for capturing the local structure information in tracing object's contour is proposed for object contour extraction. The local structure information obtained by a spotlight-like operator has been used for edge detection [6].The design of the spotlight filter is motivated by the focus of attention within the field of view in capturing the most valuable information from human's perception [7,8], and by the pheromone trail accumulation of ants' behavior [9]. In the field of human neuron study, the spotlight enhances visual information within a circumscribed region, within which information captured can be processed faster and more efficiently than those without or ignored by the spotlight [7]. The spotlight filter is also applied to SAR image, in capturing the most important signal about the designated target in [8]. In the following, the object contour extraction using local structure information by a spotlight filter is described in Section 2. Experimental results and results analysis are described in Section 3. Finally, the conclusions are drawn in Section 4.

2. THE PROPOSED METHOD

The design structure of the spotlight filter, proposed in this study, is illustrated in Fig.1.

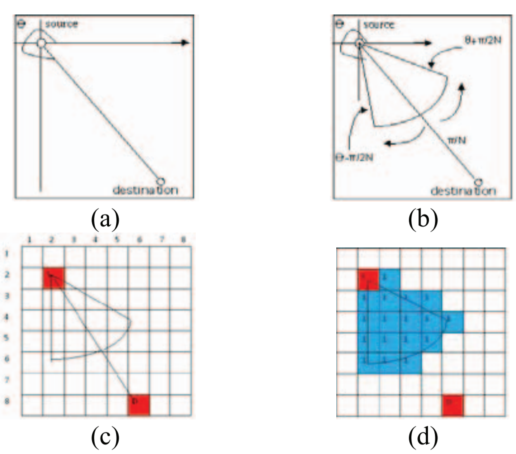


Fig. 1. The design structure of the spotlight filter. (a) The normal direction of the spotlight. (b) The spanned angle and the direction of the spotlight in radians. (c) The spotlight filter in the discrete image domain. (d) The captured pixels of the spotlight filter.

In Fig. 1(a), θ *is* the normal direction of the spotlight, which is determined by connecting the source and the destination object contour points, which represent, respectively, the starting and ending initial contour point of the object in an image. The spotlight filter in Fig. 1(b) is then characterized by the set of $\{v_i(x,y), \theta, \theta_h, r\}$, where $v_i(x,y)$ is the source point in representing the i_{th} initial edge point, $\theta_h = \pi$ /N and r, respectively, is the width, of the spotlight, and the radius of the spotlight. The spotlight filter in the discrete image domain, and the spotlight filter captured pixels, as marked in 1, are shown in Fig 1(c) and Fig. 1(d), respectively. Fig. 2 illustrates the processing flow of the object contour extraction using local structure information captured by a spotlight filter.

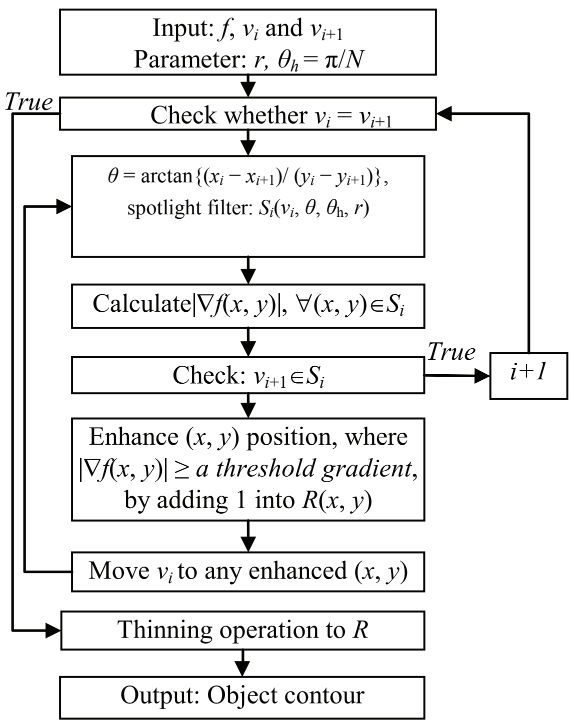
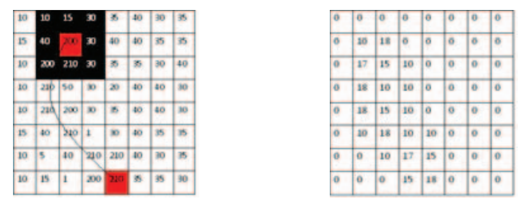


Fig. 2. The processing flow of the proposed contour extraction method.

In Fig. 2, the inputs are the object image, $f(x,y)$ and the pairs of initial contour points of the object $\{v_i(x_i\ y_i), v_{i+1}(x_{i+1}\ y_{i+1})\}$. When the initial source and destination contour points are not the same one, the proposed method will proceed by first calculating the relative angle from the source to the destination points, as the normal direction of the spotlight θ in Fig. 1(a). And the spotlight filter, S_i, is then characterized by the $S_i\{v_i, \theta, \theta_h, r\}$. For those pixels captured by the spotlight pixels, as shown in Fig.1(d), their gradients are obtained by an existing gradient operator, such as the 3x3 Sobel operator and are compared with a threshold gradient in filtering out the captured pixels with smaller gradients. A contour possibility map, $R(x, y)$, is established by first initialized with 0 value to accumulate the strength of contour possibility in the corresponding position of the spotlight filter captured pixels. For the spotlight filter captured pixels with gradient value greater than the threshold gradient, a 1 is added to the corresponding position of the pixel in $R(x, y)$ in reinforcing the strength of contour possibility at this position, and those positions for adding 1's are regarded as the source contour pixels to proceed with the spotlight filtering and to continue adding 1's to the $R(x, y)$ until the destination contour pixel, v_{i+1}, is in the spotlight is reached. Fig. 3(a) and Fig. 3(b), respectively, show the sample gradient image with a contour between two homogeneous regions and the corresponding contour possibility map, $R(x, y)$, for the image after the contour is traced by spotlight filter.



(a) (b)

Fig. 3. The illustration for the spotlight filtering with (a) a gradient image with a contour between two homogeneous regions, and (b) the contour possibility map after the contour is traced by spotlight filter.

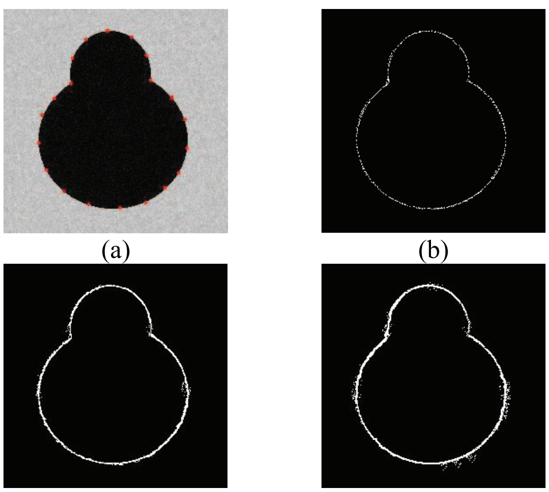
The values in the contour possibility map are similar to the accumulated pheromone in ant's foraging. The path the ant searches between the forage and the nest will be traced with pheromone with different strength. The most accumulated pheromone path will be the final path the ant will trace between the forage and the nest. Hence, a second threshold operation is performed on the contour possibility map to obtain the most possible contour, which might be a broad band extended from the source to the destination. A thinning operation, such as Guo and Hall [10], can be performed on the threshold contour possibility map $R(x, y)$ to achieve the one pixel-width object contour. Giving the pairs of initial contour points of the object $\{v_i(x_i\ y_i), v_{i+1}(x_{i+1}\ y_{i+1})\}$, the segmented contour between each pair of initial source and destination contour can hence be obtained in parallel by the proposed spotlight filtering in finally constructing a closed object contour.

3. EXPERIMENTAL RESULTS

To test the effectiveness of the proposed contour extraction, experiments for a synthetic object image with noise and a real medical image are conducted and the results are compared with those of the SCF method [3], which uses eight directional masks and calculates the corresponding gravity of gradient to trace the object's contour between each pair of initial edge point. In the experiments, all the initial edge points for the synthetic object image and the real medical image are selected by the IEPS of [3].

3.1. The preliminary experiment on synthetic object image

In the previous section, radius of the spotlight is the parameter to be selected. In conducting the preliminary experiments, 3 different radius, 4, 8, and 12 pixels are selected to test the synthetic object image with noise. Figure 4 shows the preliminary experimental results on synthetic object image. Fig. 4 (a), shows the initial edge points found by the IEPS, as indicated in red dot, superimposed on the synthetic object image. The results of the different radius of 4, 8, and 12 pixels are shown in Fig. 4 (b), (c), and (d), respectively. After the contour tracing by the spotlight filter, the spotlight with the radius of 4 appears insufficient to obtain a closed object contour, as in Fig. 4 (b), but the effect of noise is quite small. The spotlight with radius of 8, obtains better result of contour extraction than that of the spotlight filter with radius of 12, as shown in Fig. 4(c) and Fig. 4 (d), respectively. Hence, the spotlight filter with radius of 8 is selected for the following experiments.

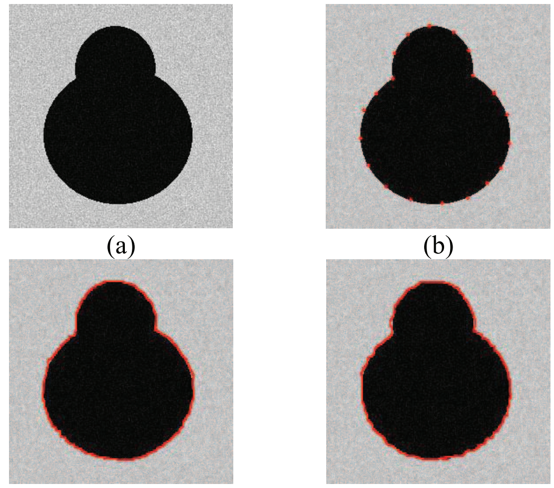


(a) (b) (c) (d)

Fig. 4. (a) The synthetic image with Gaussian noise and location of initial edge points resulted by IEPS. Contour extraction results of spotlight filtering with radius of (b) 4, (c) 8, and (d) 12.

3.2. Synthetic image experiment

Fig. 5 (a) shows the synthetic convex object image, which is composed by two black circles with different radius, added with Gaussian noise and the SNR is 23.1 dB. The width of the proposed spotlight filter, θ_h, is $\pi/3$, and the radius is 8 pixels. The initial edge points, as shown in Fig.5 (b), are again selected by IEPS [3]. There are 30 initial points for this synthetic image. The results of SCF and the proposed spotlight filtering are shown in Fig. 5 (c), and Fig. 5 (d), respectively. By visually inspecting these tracing results, both methods exhibit comparative experimental results with the contours are almost on or closed to the real edge.

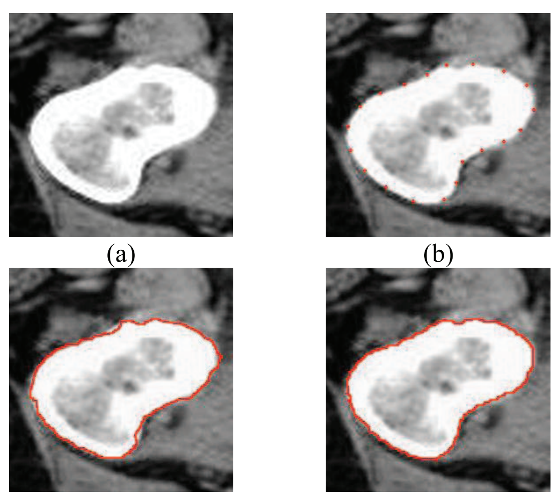


(a) (b) (c) (d)

Fig. 5. (a) The synthetic image with Gaussian noise. (b) Locations of initial edge points by IEPS. (c) Contour extraction result of SCF. (d) Contour extraction result of the proposed method.

3.3. Real image experiment

We further test the proposed method on a real medical image. For the proposed method, the expansion degree and the radius length are identical to that in the synthetic image case. A designated region of interest from a CT medical image has been chosen in this experiment, as shown in Fig. 6 (a). And 20 initial edge points have been selected by the IEPS, as shown in Fig. 6 (b). The results of SCF and the proposed method are shown in Fig. 6 (c), and Fig. 6 (d), respectively. By examining these tracing results, one can see that the true contour is more accurately captured by the proposed method than by the SCF method.



(a) (b) (c) (d)

Fig. 6. (a) The ROI from a real medical image. (b) Locations of initial edge points by the IEPS. (c) Contour tracing result of SCF. (d) Contour tracing result of the proposed method.

The quantitative comparisons of the contour extraction results for both the synthetic and real image are also provided in Table 1, in terms of the error rate, i.e., the false positive, which is defined as the ratio of false detected initial boundary pixels to the number of total true boundary pixels. The total true boundary pixels are defined as the two pixel-wide edges between the object and the background within the images. Table 1 shows that the proposed method appears to achieve smaller error rate than the SCF for both the synthetic and real images.

Table 1. Quantitative comparisons in terms of error rate

Methods / Images	SCF	The proposed method
Synthetic	85/732=11%	62/732= 9%
Real	196/1458=13%	135/1458=9%

The proposed spotlight filter is further applied to a synthetic image with U-shape object and a real medical image and the results are compared with those of the SCF, which are shown in Figure 7. The initial contour points are selected by the IEPS. One can see that more accurate contours for the synthetic and real images are obtained by the proposed method, as shown in Fig. (a) and Fig(b), respectively, than those obtained by the SCF, as shown in Fig. 7 (c), and Fig. 7 (d).

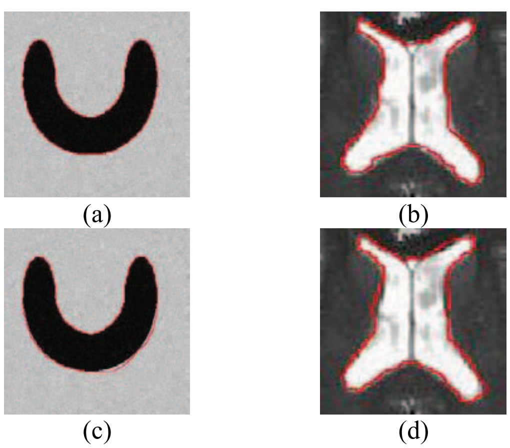


Fig. 7. The experimental results of the proposed method in comparing with those of SCF. The results of the proposed method for (a) the synthetic image, and (b) the real medical image. The results of SCF method for (c) the synthetic image, and (d) the real medical image..

4. CONCLUSIONS

A spotlight filter for capturing local structure information along the contour path between two initial contour points for object contour extraction is proposed in this paper. The proposed spotlight filtering is motivated by the focus of attention within the field of view, which was studied by physiological field and the advanced radar signal field in capturing the most valuable information from human's perception. The spotlight filter is able to capture the local structure information for object contour extraction and is tested on the synthetic object image and the real medical image. The experimental results demonstrated that the proposed contour extraction method obtained better results than other existing method for both images by visual inspection.

5. REFERENCES

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