IMPROVEMENT OF CONTOUR EXTRACTION PRECISION OF ACTIVE CONTOUR MODEL WITH STRUCTURING ELEMENTS

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ABSTRACT

To achieve enhanced image recognition, it is necessary to accurately extract the contour of the recognition target from the input image in a preprocessing step. Contour extraction methods based on the active contour model(Snakes) require the operator to specify the parameter values that best catch the shape of the target. However, it is difficult to guess the parameter values since the relationship between target shape and values is unclear. One solution is the active contour model with structuring elements since its parameters are easily determinable. However, this method is not really practical since it fails if the boundary between the target and its background is not clear. Moreover, it is not efficient for natural images, since the backgrounds are not monotone. This paper introduces an improved contour extraction method based on the Sobel filter and thresholding.

***Index Terms*—** Contour Extraction, Active Contour Model, Structuring Elements, Image Processing

1. INTRODUCTION

Image recognition technologies have been studied in various fields such as the recognition of white lines to realize Intelligent Transport Systems(ITS) [1]. To achieve these technologies, it is necessary to accurately extract the contour of the recognition target from the input image.

Most contour extraction methods are based on Snakes[2] and Level Set Method[3]. The dominant problem with Snakes lies in determining the values of the parameters related to the energy functions. Moreover, Level Set Medthod has the problem of high computional cost. These weakness led to the proposal of the active contour model with structuring elements; its parameters are easy to determine [4]. In this technique, the move bar created from the initial contour is updated toward the target which represents the boundary. The criterion used to stop the update is a constant threshold for concentration. However, this method is not effective for contour extraction from natural images since they exhibit non-uniform backgrounds. We call the active contour model with structuring elements the conventional method hereafter.

In this paper, we indicate the issues of the conventional method, and propose an improved contour extraction method. We evaluate the conventional and proposed method by extracting contours from natural images. The results show the effectiveness of the proposed method.

2. ACTIVE CONTOUR MODEL WITH STRUCTURING ELEMENTS

The conventional method and its issues are introduced here. The dominant factors are the control point, move bar and closed curve. The control point forms a closed curve to capture the target shape. An update of a control point is driven by the slope calculated from the move bar whose center corresponds to a control point.

2.1. Algorithm

The algorithm of the conventional method is shown below.

1.Creation of Initial Contour

N initial contour control points are prepared around the target. The positional coordinates of control points are expressed as $P_n = (x_n, y_n), (n = 1, \cdots, N)$. In general, the initial control points placed around the target are connected, P_n to P_{n+1}, to form a circle.

2.Creation of Move Bar

For control point P_n, slope a is calculated from the positions of neighboring control points P_{n-1}, P_{n+1}. Slope a for P_n is given as;

$$a = \frac{y_{n+1} - y_{n-1}}{x_{n+1} - x_{n-1}}. \tag{1}$$

Next, move bar $B_n (n = 1, \cdots, N)$ which consists of slope a and length L is created for each P_n (Fig.2(a)).

3.Movement of Move Bar

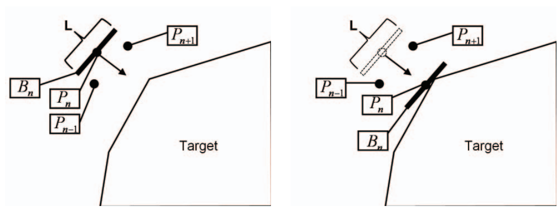
Slope c, the normal of a, is calculated for move bar B_n. Slope c is

$$c = -\frac{1}{a}. \tag{2}$$

B_n is then moved in the direction of slope c (Fig.2(b)). If B_n crosses the target, the movement is terminated. These processing steps are applied to move bars B_1 to B_N for updating control points $P_1, \cdots, P_N$. When all move bars have not been updated, the algorithm terminates. Otherwise, go to step 4.

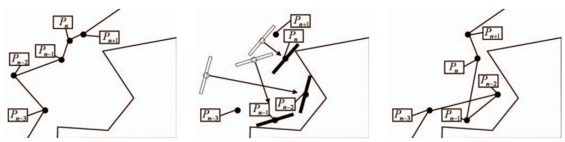
4.Addition and Removal of Control Point

If the distance between P_n and P_{n+1} is longer than D_{max}, a control point is added at the midpoint of $P_n$and P_{n+1}. If the distance is shorter than D_{min}, control point P_n is removed. After no more addition or removal operations are possible, return to step 2.



(a) Creation of move bar (b) Movement of move bar

Fig. 1. Creation and movement of move bar



(a) (b) (c)

Fig. 2. Outline of crossing

2.2. Issues

The conventional method is mainly applied to binary images and Optical Coherence Tomography(OCT) images in gray scale [4]. In gray scale image analysis[4], the move bar slides toward the target until it reaches the pixel whose concentration value is larger than a defined threshold. In this case, the concentration values of target and background must be known to stop the update algorithm. Moreover, the image background must be monotone. This makes it impossible to apply the conventional method to natural images since the backgrounds are not monotone and contain complex patterns.

3. PROPOSED METHOD

This section describes our two enhancements of the conventional method. One is update of the move bar. The other is relocation of the control point.

3.1. Determination of Move Bar Movement

The conventional method uses a single threshold to detect the boundary. It is hard to say that the conventional method is not a general approach, since it can be used for images whose intensities are clear and known. Here, it is considered that the gradient around the target is generally greater than its background shading. If the gradient around the move bar becomes large, movement of the move bar should be stopped. On the other hand, the update algorithm is repeated while the gradient is small. For intermediate gradients, adaptive update based on the surrounding gradient is employed to control the movement of the move bar. This approach yields the appropriate determination of move bar update. These processes are applied to the destination point of the move bar. The proposed algorithm is as follows.

1.Sobel Filter

Gradient f is calculated for a control point by using the Sobel filter

Table 1. contour extraction parameters

Method	N	L	D_{max}	D_{min}	HT	LT
Conventional	144	5	10	2	-	-
Proposed	144	5	10	2	200	100

2.Hysteresis Threshold Processing

The hysteresis threshold is adopted to determine to handle the use of multiple thresholds. A high threshold(HT) and low threshold(LT) are prepared to decide the next processing operation from a gradient. There are three cases according to f.

$f >$ HT: Stop the movement of the move bar since the destination point is an edge.

HT$\geq f \geq$LT: Calculate gradients $f'_1, \cdots, f'_8$ for eight neighbor points using the Sobel filter to determine if update is to be performed or not. If one or more gradients is greater than LT, that is, $f'_1 \geq$LT$\cup \cdots \cup f'_8 \geq$LT, stop the movement of move bar. Otherwise, i.e. LT$\geq f'_1 \cap \cdots \cap$LT$\geq f'_8$, continue the update algorithm.

LT$\geq f$: Continue the update algorithm.

3.2. Relocation of the Control Points

An example of control point relocation is shown in Fig.2; the initial state is shown in Fig.2(a). Positions of the move bars before and after movement are shown in Fig.2(b). When we focus on control point P_{n-1}, P_{n-2}, line segments $P_{n-3}\ P_{n-2}$ and $P_{n-1}\ P_n$ cross each other as shown in Fig2(c) due to control point movement. If the distance between P_n and P_{n+1} is longer than D_{max}, a control point is added at the midpoint of P_n and P_{n+1}. This means that unnecessary addition or reduction operations occur. Therefore, a move bar is not created and moved correctly.

We consider that the outline forms a circular route. In order to prevent line crossing, we adopt the Traveling Salesman Problem(TSP). In this paper, we employ the 2-opt and or-opt method which is a general approach to solving TSP[5]. These methods are repeated until the circular route can not be updated any further.

4. CONTOUR EXTRACTION EXPERIMENT

Fig.3(a), 4(a), 6(a)(481$\times$321, JPEG), 5(a)(321$\times$481, JPEG) were prepared as evaluation images. We extract contours from these images by applying the conventional and proposed methods. The ground truth (GT) is the manually extracted boundary. GT images and contour extraction results are indicated in Fig.3(b)$\sim$6(b) and Fig.7(a)$\sim$10(b), respectively. The GT images are taken from the Berkeley dataset. White lines in the result images are extracted contours. Parameters used in this simulation are presented in Table 1.

The conventional method yielded partial contour extraction, see Fig.7(a),8(a). However, as described in Section 3.2, there are some crossed outlines due to inappropriate control point movement, which degrades the accuracy of contour extraction. The contour in the upper side of the image is correctly extracted from Fig.9(a). The estimated contour does

Table 2. Evaluation Results

Original image	Method	NPRI	DI
Fig.3(a)	Conventional: Fig.7(a)	0.798	0.040
	Proposed: Fig.7(b)	0.893	0.025
Fig.4(a)	Conventional: Fig.8(a)	0.752	0.051
	Proposed: Fig.8(b)	0.920	0.022
Fig.5(a)	Conventional: Fig.9(a)	0.579	0.102
	Proposed: Fig.9(b)	0.909	0.026
Fig.6(a)	Conventional: Fig.10(a)	0.622	0.207
	Proposed: Fig.10(b)	0.648	0.188

not follow the object at and around the middle point, since a gray region in the background image is captured as a contour. Tree part in Fig.10(a) is captured as a contour. The contours of three owls are extracted so as to cover.

Finally, we focus on results of the proposed method. As shown in Fig.7(b), the estimated contour follows the GT image. However, the contour around the airplane wing is extracted incorrectly. It is considered that the move bar relocation failed to catch the sharp edge part between the body and wing. This result is also presented in Fig.8(b). However, The estimated contor in Fig.10(b) is similar to that in Fig.10(a). Fortunately, the crossed outlines in Fig.7, 8 are removed by applying either the 2-opt and or-opt method. Moreover, the contour in Fig.9 is correctly extracted due to use of the Sobel filter and Hysteresis threshold.

5. EVALUATION AND CONSIDERATION

This section provides a quantitative evaluation of the proposed and conventional methods. We use NPR Index and Dongen Index as the evaluation criteria[6]. NPR Index(NPRI) and Dongen Index(DI) are often used to evaluate region segmentation. NPRI expresses the degree of coincidence between an extracted contour and GT. NPRI = 1 means that the extracted contour coincides with GT. On the other hand, DI represents the difference between an extracted contour and GT. DI = 0 means that the contour extraction result and GT are the same.

5.1. Evaluation Result

Each image in this experiment includes several GT images. However, DI evaluates a result and GT image on one to one. We average the calculated DI evaluation values for each method. As shown in Fig.7(a), 8(a), crossing of extracted contour is possible with the conventional method. Therefore, we define a closed curve bounded by a white line as an outline. NPRI and DI for each image are shown in Table 2.

From Table 2, the differences between the conventional and proposed method in terms of NPRI range from 0.026 to 0.330. Differences in DI range from 0.015 to 0.076. These results indicate that the proposed method detected contours more correctly than the conventional method for all images. This means that the accuracy of contour extraction is improved by using the proposed method.

We now focus on the differences between images. A comparison of Fig.7 and 8 and Fig.10, shows that NPRI and DI for Fig.9 are much improved by the proposed method. It is considered that the crossed outline has a small effect on NPRI and DI, since these criteria focus on the degree of confidence for a closed region. Gray region of the background in Fig.9(a) is captured as a contour. Thus, the area of the closed region surrounded by the outline is greatly different from its GT image. This yields the improvement seen in Fig.9 in both NPRI and DI. Moreover From the above, the precision is improved for each image by applying the proposed method.

6. CONCLUSION

In this paper, we indicate some issues related to the conventional method. To overcome the weakness of the conventional method, we enhance the conventional method by adding the Sobel filter and thresholding. An evaluation of the conventional and proposed methods was performed by extracting contours from natural images. The proposed method yields fewer errors between the extracted and true outlines than the conventional method. That is, improved contour extraction precision was confirmed in our experiment. For the future, we need to improve contour extraction precision at sharp edges, and apply the proposed method to various images.

7. REFERENCES

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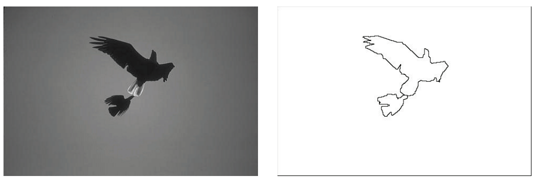
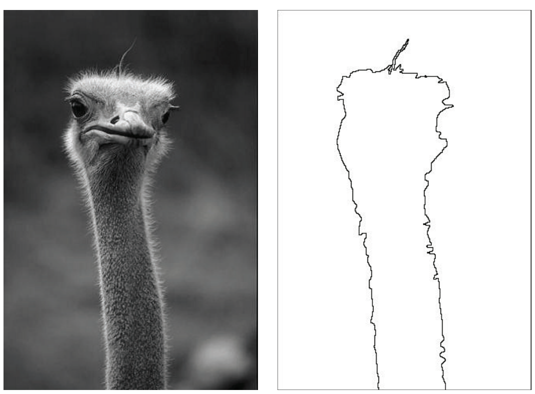
(a) Original image (b) GT image

Fig. 3. Image 1



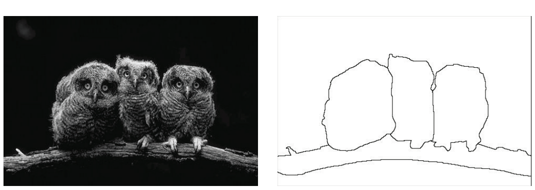
(a) Original image (b) GT image

Fig. 4. Image 2



(a) Original image (b) GT image

Fig. 5. Image 3



(a) Original image (b) GT image

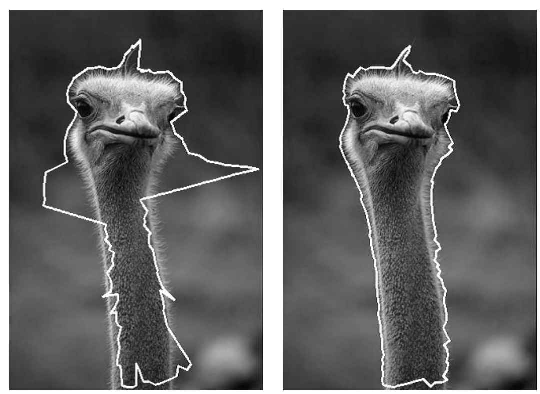
Fig. 6. Image 4

(a) Conventional (b) Proposed

Fig. 7. Contour extraction result for Fig.3(a)

(a) Conventional (b) Proposed

Fig. 8. Contour extraction result for Fig.4(a)



(a) Conventional (b) Proposed

Fig. 9. Contour extraction result for Fig.5(a)

(a) Conventional (b) Proposed

Fig. 10. Contour extraction result for Fig.6(a)