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Adaptive Thinning Algorithm for External Boundary Extraction

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Abstract

The process of extracting external boundary of an object is a very important process for recognizing an object in the image. The proposed extraction method consists of two processes: External Boundary Extraction and Thinning. In the first step, external boundary extraction process separates the region representing the object in the input image. Then, only the pixels adjacent to the background are selected among the pixels constituting the object to construct an outline of the object. The second step, thinning process, simplifies the outline of an object by eliminating unnecessary pixels by examining positions and interconnection relations between the pixels constituting the outline of the object obtained in the previous extraction process.

As a result, the simplified external boundary of object results in a higher recognition rate in the next step, the object recognition process.

Keywords: *Image Enhancement, Image Thinning Algorithm, Image Restoration, External Boundary Extraction, Noise Elimination, Image Filtering, Image Processing, Pattern Recognition*

1. Introduction

The development of science and technology led to a convenient life, but in terms of personal information protection, it became a risk. As a result, various authentication methods such as fingerprint recognition, iris recognition, signature recognition, and facial contour recognition have been developed. These identity authentication systems basically go through image processing and recognition processes for input images obtained by optical equipments. Representative image processing procedures include Image Restoration and Image Enhancement [1]. Image recognition processes include Feature Extraction, Pattern Recognition, and Image Analysis [2] and others. What is important in these various processes is to remove problems in the input image caused by the mechanical problems of optical devices effectively during the image processing, thereby improving the recognition rate of recognizing an object in the input image in the next image recognition process.

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2. The Related Works

In order to recognize an object in the input image, contour of the object is first obtained by Edge Detection [3]. Then, thinning algorithm is used to simplify the contours. The Zhang-Suen Algorithm [4] is widely used as a typical thinning technique. The advantage of this technique is that it is easy to implement and the computational process is simple. However, the disadvantages of this technique are 1) it does not remove the contours in inside of the object created by the contour detection method. The contours in inside of the object result in lower recognition rates in later recognition processes. 2) There are unnecessary pixels among the pixels constituting the outline of the object. These unnecessary pixels increase the processing time. In this paper, we introduce an improved thinning technique which removes contours in inside of the object created by the contour detection method and also minimizes the number of pixels constituting the outline of the object, thereby increasing the recognition rate and shortening the processing time.

3. The Main Subject

In the field of image processing techniques, the process of extracting external boundary of an object is important factor for recognizing the object in the image. In this paper, we propose a thinning algorithm that obtains better outline results than the existing techniques.

3.1 The Basic Concept

The thinning technique is closely related to the process of extracting external boundary needed to recognize the object in the image. To extract the outline of an object, edge detection technique is first applied to the input image. In this process, a black and white binary image is created that represents the difference in brightness between neighbor pixels. The thinning technique is an image processing technique that finds the shape of an object in an image by changing thick lines in a binary image to thin lines of size 1.

The proposed method consists of two steps: External Boundary Extraction and Adaptive Thinning. In the first step, the external boundary extraction process first finds an area belonging to the background on the binary image representing the difference in brightness between adjacent pixels and then separates the area representing the object from the background. Object in a binary image is composed of an external boundary representing the outer shape of the object and an inner area. Therefore, only the pixels adjacent to the background are selected among the pixels constituting the object. These pixels constitute the outline of the object. Then, all pixels belonging to the inner area except the outline of the object are converted to the color of background. As a result, the outline of the object is represented in black color, and the interior of the object and the background are represented in white color.

In this process, the outline of the object is in contact with the background and the inside of the object simultaneously. Thus, in the first step, the external boundary extraction process, the outline is formed by selecting only direct neighbor pixels adjacent to the background among the pixels constituting the object, in order to distinguish the background and the inside area of the object. For this reason, edges in the binary image obtained as a result of the external boundary extraction process form stepped shapes composed of horizontal or vertical lines of direct neighbor pixels.

The second step, the thinning process, minimizes the outline of the object by eliminating unnecessary pixels by examining the positions and interconnection relations of the pixels composing the outline of the object obtained in the previous process. In other words, a 3x3 mask is applied to each pixel constituting the binary image created by the external boundary extraction process. Then, the number of neighbor pixels belonging to the outline is calculated by examining whether each of the eight neighbor pixels of the pixel located at the center belongs to the background, the inside of the object, or the external boundary. As a result, the following four cases are generated according to the number of neighbor pixels belonging to the external boundary in the 3x3 mask.

Case 1) If the number of neighbor pixels belonging to the external boundary in the 3x3 mask is 0: The pixel located at the center is an isolated pixel because it is alone in the background or inside of the object. So the pixel located at the center of the mask is removed.

Case 2) If the number of neighbor pixels belonging to the external boundary in the 3x3 mask is 1: The pixel located at the center is the end pixel because it is connected to only one neighbor pixel. So the pixel located at the center of the mask is removed.

Case 3) If the number of neighbor pixels belonging to the external boundary in the 3x3 mask is 2 or more and 7 or less: The pixel located at the center is present or removed according to the position and interconnection relation with neighbor pixels. When the center pixel is removed from the mask of size 3x3, if the interconnection relation of the neighbor pixels belonging to the external boundary is maintained, the center pixel is removed. However, when the pixel located at the center of a 3x3 mask is removed, if the neighbor pixels belonging to the external boundary cannot be maintained in the interconnection relationship, then the pixel positioned at the center of the mask remains.

Case 4) If the number of neighbor pixels belonging to the external boundary in the 3x3 mask is 8: The pixel located at the center is an inner pixel completely surrounded by 8 neighbor pixels. So, the pixel at the center remains.

As a result, the second step, thinning process, simplifies the external boundary of the object with the minimum number of pixels by removing unnecessary pixels while maintaining the connection relationship between pixels constituting the external boundary of the object. The simplified external boundary of an object makes the calculation process simple and also shortens calculation time in the next step, the object recognition process, and consequently increases the recognition rate.

3.2 The Adaptive Thinning Algorithm

The external boundary extraction process and the thinning process proposed in this paper will be described in more detail through the following algorithm.

External Boundary Extraction process

Step 1) Draw a blue horizontal line at the top and the bottom of the input image, and draw a blue vertical line at the leftmost and the rightmost positions.

Step 2) The color is obtained for each pixel in the input image.

Step 2.1) If this color is white belonging to the background, colors of four direct neighbor pixels located above, below, left and right of this pixel are obtained.

Step 2.2) If any of these direct neighbor pixels has a blue color, the color of the pixel is changed to blue.

Step 3) If there is a pixel changed to blue while executing Step 2, move back to Step 2 and execute again. If there is no pixel changed to blue, move to Step 4.

Step 4) Find color of each pixel in the input image.

Step 4.1) If the color is neither blue nor green, obtain the colors of the eight neighbor pixels around this pixel.

Step 4.2) If any of these eight neighbor pixels has a blue color, the color of the pixel is changed to green.

Step 5) If there is a pixel changed to green while executing Step 4, move back to Step 4 and execute again. If there is no pixel changed to green, move to Step 6.

Step 6) Find color of each pixel in the input image.

Step 6.1) If this color is not green, change the color of this pixel to white. White pixels correspond to the background or the inside of an object.
Step 7) Color is obtained for each pixel in the input image.
Step 7.1) If the color is green, change the color of this pixel to black. Black pixels correspond to the external boundary of the object.

Adaptive Thinning Process
Step 1) Find color of each pixel in the input image.
Step 1.1) If this color is not white belonging to the background, check colors of the eight neighbor pixels of this pixel.
Step 1.2) For each of the eight neighbor pixels, if the color is white, 0 is stored in the corresponding position of the 3x3 mask, and also if the color is black, 1 is stored in the corresponding position of the 3x3 mask.
Step 1.3) Calculate the number of black pixels that represent the outline in a 3x3 mask.
Step 1.4) There are 4 cases according to the number of neighbor pixels corresponding to outline in 3x3 mask:
Case 1) If the number is 0: The pixel located at the center of the mask is an isolated pixel. Since the pixel at the center of the mask should be removed, change it to white, which is the background color.
Case 2) If the number is 1: The pixel located at the center of the mask is an end pixel. Since the pixel at the center of the mask should be removed, change it to white, which is the background color.
Case 3) If the number is 2 or more and 7 or less: In the case of removing the pixel located at the center of a 3x3 mask, if the interconnection relation of the neighbor pixels belonging to the outline is maintained, the pixel at the center of the mask is changed to white, which is the background color. However, if the interconnection relation of neighbor pixels belonging to the outline is broken, the pixel at the center of the mask is not changed.
Case 4) If the number is 8: The pixel located at the center of the mask is an inner pixel. The pixel at the center of the mask is not changed.
Step 2) If there is a pixel whose color is changed to white while executing Step 1, move back to Step 1 and execute again. If there is no pixel changed to white, the adaptive thinning process is completed.

3.3 The Results

The following images show the result of executing the proposed thinning algorithm to extract contour line of a chili. Figure 1 (a) shows an input image with 640x640 resolution for a chili. Figure 1 (b) shows the result of detecting the contour of the object by applying the edge detection method to the input image, but not only the contour of the object but also the contours of the inside were detected. These contours of the inside of the object are unnecessary in the recognition process and should be removed. Figure 2 (a) shows the result of the external boundary extraction process proposed in this paper. The contours inside the object have been removed. Figure 2 (b) shows the result of the thinning process proposed in this paper. By removing unnecessary pixels to maintain the connection between the pixels constituting the outline of the chili, the outline of the object is made as simple as possible. As a result, the simplified outline of the object improves the recognition rate in the object recognition process and also shortens the calculation process.

3.4 The pros and cons of the proposed adaptive thinning algorithm

Similar to the existing thinning techniques, there are advantages and disadvantages in the thinning algorithm proposed in this paper. Advantages include: 1) Conventional techniques use difficult formulas, but the proposed method is easy to understand and satisfactory. 2) It increases recognition rate by removing unnecessary contours of the inside of the object during recognition process. 3) It simplifies calculation process by making the external boundary as simple as possible. As a disadvantage, it is possible to obtain different results according to the edge threshold value used when applying the edge detection method to the input image as the conventional techniques do.

4. Conclusion and Future work

In this paper, we describe adaptive thinning technique for extracting external boundary of object in an input image. By simplifying the external boundary of object, the recognition rate of the object in the input image is increased and the processing procedure is shortened. The future researches are based on the research of this paper, and they are the method of expressing the external boundary of an object by corners and the object recognition method using it.

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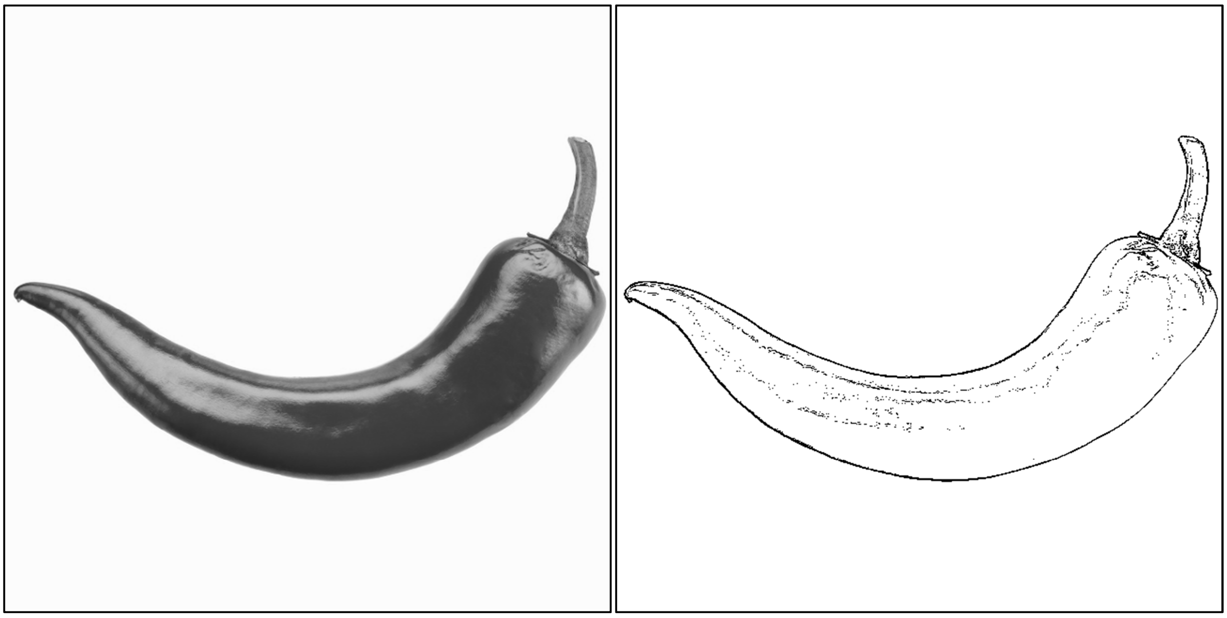

Figure 1. (a) Chili (b) Edge Detection of Chili

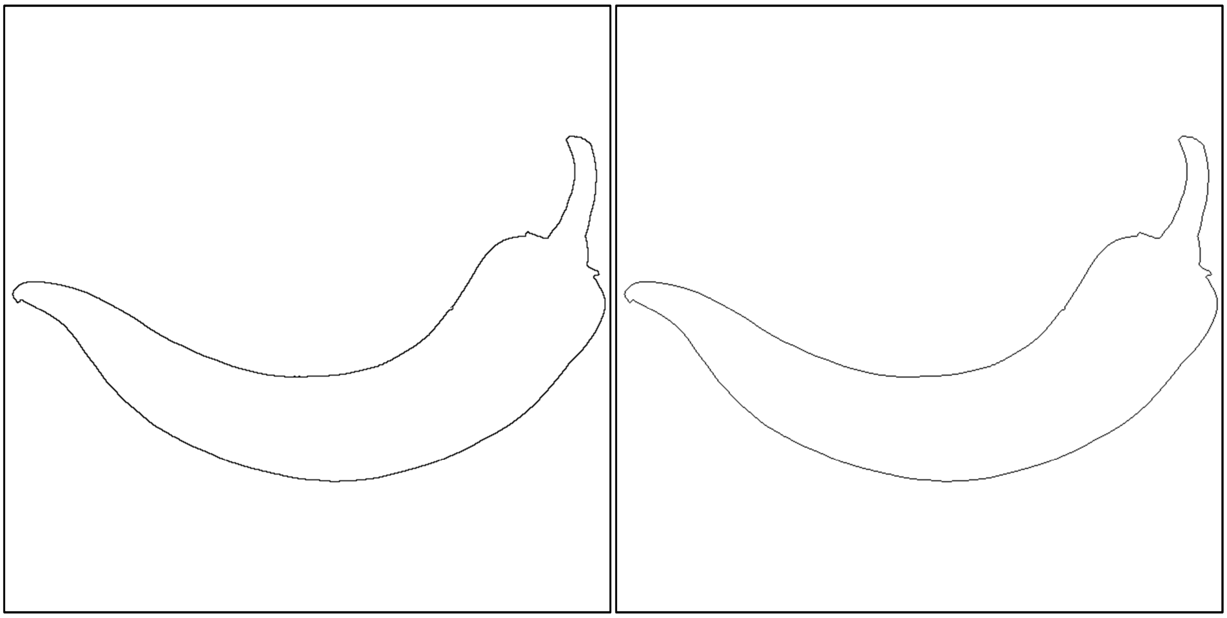

Figure 2. (a) External Boundary Extraction (b) Adaptive Thinning