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Research Article

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A Segmentation and Localization Algorithm for Silkworm Cocoons Based on Local Threshold and Regional Features

Shengjie Gong[1], Mingxin Yuan[1,2], Leihui Huang[1], Yafeng Jiang[1,2]

[1]School of Mechanical and Power Engineering, Suzhou Institute of Technology, Jiangsu University of Science and Technology, Zhangjiagang, China
[2]Zhangjiagang Industrial Technology Research Institute, Jiangsu University of Science and Technology, Zhangjiagang, China

Abstract In order to realize the precise visual segmentation during automatic picking of silkworm cocoons, a segmentation and localization algorithm is presented based on local threshold and regional features. In this algorithm, the original silkworm cocoon image is first grayscaled. Then, the blood cocoons are detected and marked. Next, the gray scale of the marked silkworm cocoon image is enhanced to improve the image contrast. Finally, the silkworm cocoons are visually segmented based on local threshold. Each grid outline in the silkworm cocoon image is extracted by region features to complete image recognition and coordinate localization. The image processing results show that, the segmentation and localization algorithm based on local threshold and regional features not only can realize the recognization of blood cocoons, but also can complete segmentation of grid outline in the silkworm cocoon images. Compared with other algorithms, the localization accuracy of the proposed algorithm is higher, which verifies its effectiveness.

Keywords silkworm cocoon; blood cocoon; threshold segmentation; regional features; coordinate localization

1. Introduction

In recent years, with the increase of labor cost, the automatic picking technology for silkworm based on vision has become the focus of attention [1]. However, the complex environmental background, silk adhesion and other interference factors in actual picking add difficulty to image recognition in picking. How to improve the target recognition and segmentation precision is a technical difficulty in the automatic picking of silkworm cocoons. So, many scholars at home and abroad have carried out related research. By analyzing the texture features of the cocoon edge, Zhang *et al* [2] achieves the separation of the target and the background, and then completes the segmentation of the silkworm cocoon image using the edge tracking segmentation algorithm. Hua *et al* [3] gets many images of cocoons with high-speed shooting. Then transfers these graphs to black and white ones. By counting the pixels of these graphs, it can reflect accurately the cocoon superficial area. To change the lower efficiency of silkworm cocoon picking, Liu *et al* [4] put forward an algorithm of cocoon image segmentation and coordinate localization based on color and area characteristics, and a cocoon harvestor was designed based on machine vision. To solve the high false sorting rate during the manual mulberry silkworm cocoon sorting, Chen *et al* [5] used the MATLAB software for image processing and calculation of color images of mulberry silkworm cocoons. The research results show that under the conditions of color image shooting with multiple light sources and accurate camera calibration, after color space transformation, image intensification and binaryzation of mulberry silkworm cocoon color image, the stained surface area of mulberry silkworm cocoon can be auto-detected accurately and rapidly. The above-described image segmentation methods for silkworm cocoons are difficult to accurately segment the images with a large difference in background gradation, and it is impossible for them to detect the blood cocoons. In view of the above deficiencies, the silkworm cocoon images are segmented firstly based on the local threshold in this paper; Then, the morphological opening operation of the segmented cocoon images is carried out; Finally, each grid outline in a silkworm cocoon image is coordinately located based on the connected domain marker and the region feature extraction method, which improves the segmentation and localization precision of the silkworm cocoons.

2. Preprocessing of silkworm cocoon images

The silkworm cocoon images captured by video camera are usually in RGB format. The three components (i.e. R, G, B) in the RGB color space are related to each other. During image processing, the three color channels are processed at the same time, and the amount of calculation is very large. In order to solve the problem, the RGB image is transformed into grayscale image, and the grayscale image is a two-dimensional image, which reduces the calculation amount of the subsequent processing [6]. Figures 1 and 2 are the original RGB image and grayscale image respectively.

Figure 1: Original RGB image

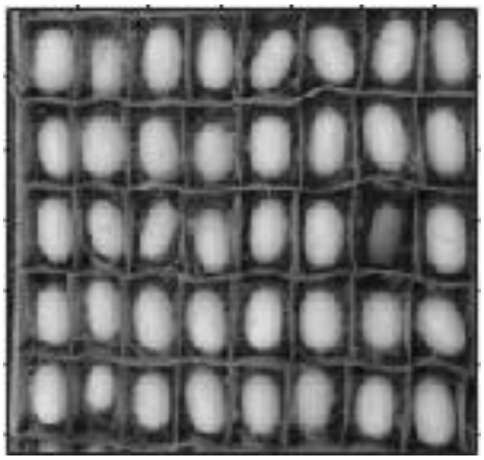


Figure 2 : Grayscale image

In addition, some blood silkworm cocoons will inevitably occur in actual production. This type of silkworm cocoons cannot be mixed with good silkworm cocoons. Therefore, it is necessary to be able to detect such bad cocoons in automatic picking. In view of this, the blood cocoons are first identified and marked in this article. Figure 3 shows the blood cocoon image after marking.

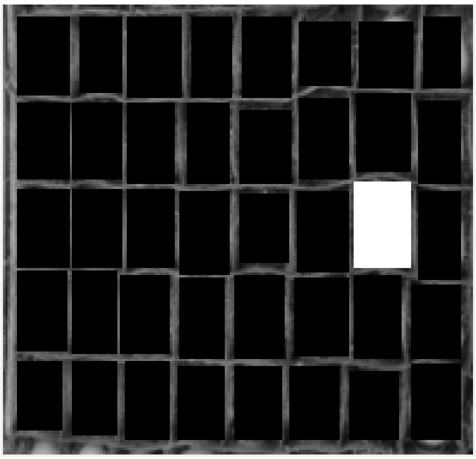


Figure 3: Blood cocoon image after marking

From the figure, it can be seen that the entire silkworm cocoon image has only the grid outline after the blood cocoon is marked. The grid outline is the main segmentation target, and the automatic picking of the silkworm cocoons requires the precise segmentation and localization of the grid outline. However, we all see that the gray value of the grid outline in the image is so low that it is not conducive to subsequent segmentation recognition.

Therefore, the gray value of the grid outline is improved by histogram equalization, grayscale linear transformation and Laplacian sharpening. Figure 4 is a gray histogram of an original silkworm cocoon image.

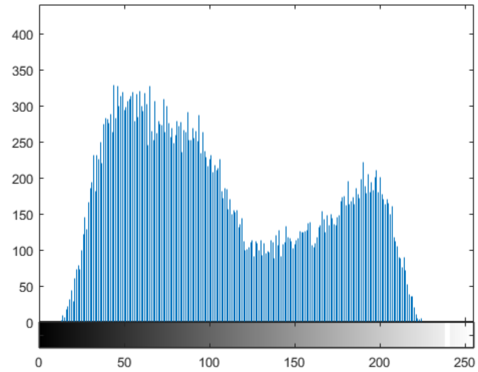
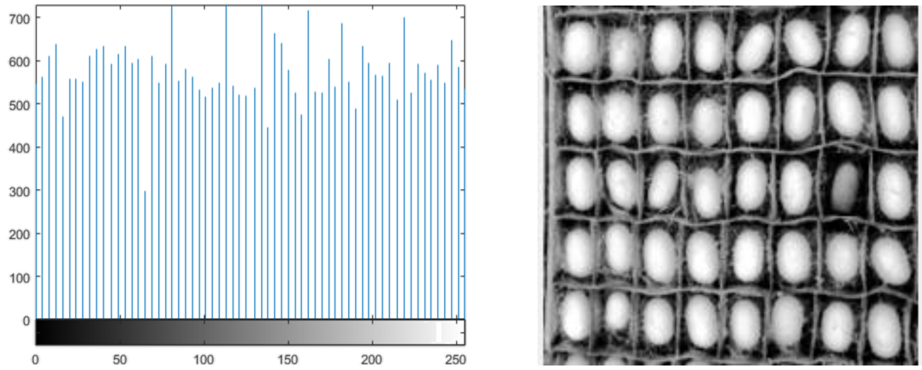


Figure 4: Gray histogram of the original image

From the figure, it can be seen that the gray scale distribution is narrow and the image contrast is low. Figure 5 shows the histogram equalization.



(a) Histogram image (b) Equalized image

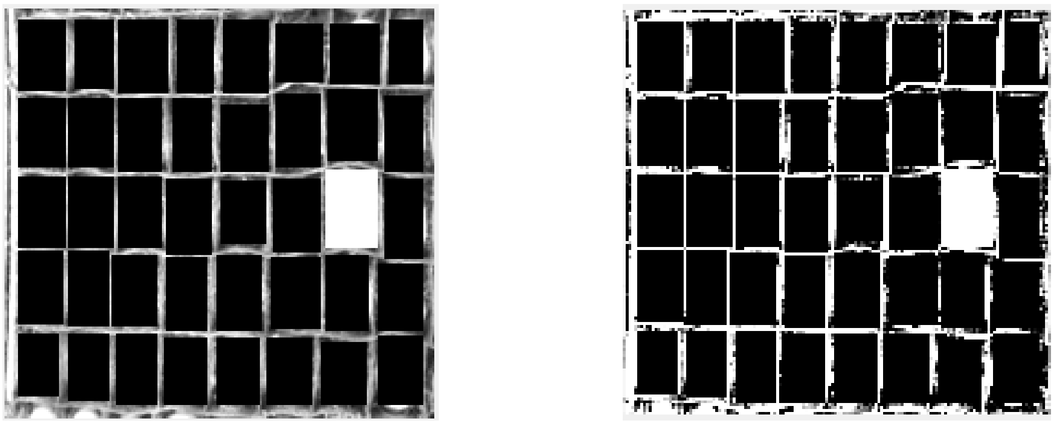
Figure 5: Histogram equalization

From the figure, it can be seen that, after the gray level is equalized, the gray level of the grid outline becomes high, but the effect is not very obvious. Gray linear transformation realizes gray enhancement of the grid outline through grayscale mapping of primary function. Eq. (1) gives the expression of the primary function.

$$y = kx + b \tag{1}$$

where, k is the slope of the grayscale transformation function, b is the luminance value, x is the original grayscale, and y is the transformed grayscale.

Because the grayscale value of the grid outline in a silkworm cocoon image is low, k must be greater than 1. After several numerical simulations, k is taken as 3 and b is taken as 0 in this paper.



(a) Grayscale transformation *(b) Laplacian sharpening*

Figure 6: Grayscale enhancement image

After the image gradation is transformed, the grid outline gradation is significantly improved. However, from the actual segmentation effect, some outlines are intermittent, and it is impossible to accurately segment all the outlines. In order to solve the problem, the image is sharpened by the Laplacian operator, and the sharpening can make the edge of the outline more prominent, which helps to segment the squares efficiently. Figure 6 shows the image after grayscale enhancement.

3. Threshold segmentation of silkworm cocoons

At present, the existing visual segmentation methods of silkworm cocoons are mainly based on global threshold segmentation; however, silkworm cocoons are often difficult to be completely segmented due to the influence of illumination. Therefore, the local threshold segmentation method is adopted in this paper.

3.1. Division of grid outline of silkworm cocoons

First, the division of grid outline is performed on the cocoon image. The size of the grid outline is selected according to the size of the image. The size of the silkworm cocoon image in this paper is 188*197. Assuming that the grid outline is 30 in size, since 30 cannot be divisible by 188 and 197, the grid outlines at the far right, bottom right and bottom of the image are incomplete. During image processing, we need to process these three parts and the normal area separately.

3.2. Iterative threshold segmentation

After completing the division of grid outlines in a silkworm cocoon image, the threshold segmentation process needs to be performed for each region. The iterative threshold segmentation method is used to segment each grid outline in this paper. First, the average gradation value of the grid outline is taken as an initial threshold, and the grid outline image is divided into two parts by gradation. Then, the average gray value of the two parts is taken as the new gray threshold of the grid outline, and the iterative selection of the threshold is performed again until the newly obtained threshold is less than a certain value compared with the previous threshold, and then the threshold iteration ends. Based on the obtained segmentation thresholds for each outline, the final binarization map of the silkworm cocoon image can be obtained, as shown in Fig. 7.

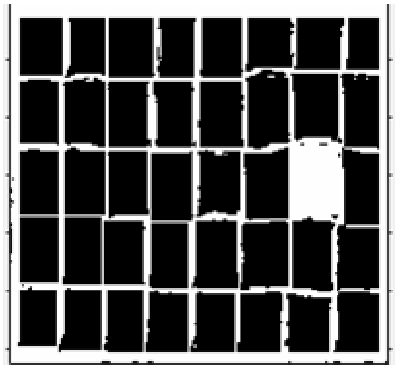


Figure 7: Segmentation image based on local threshold

From the figure, it can be seen that, not only are all the grid outlines segmented, but the shape of the outline is basically the same as the shape of the original image outline.

4. Locating of silkworm cocoon

After the silkworm cocoon image is visually segmented, the position of each grid square needs to be located. The goal of locating is to determine the starting point position of the automatic picking and the distance in the x and y directions when the knife is gone.

4.1. Morphological open operation

Open operation refers to the process of etching and re-expanding for an image. The opening operation smoothes the edges of the object and separates the two objects that the edge touches. Fig. 8 is a silkworm cocoon image processed by the opening operation.

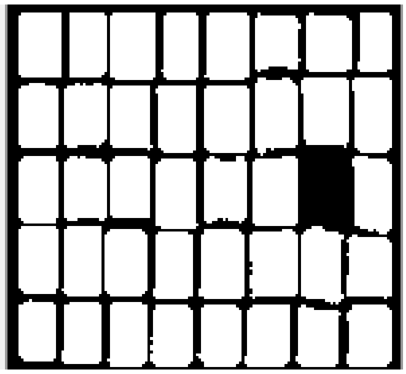


Figure 8: Silkworm cocoon image after open operation

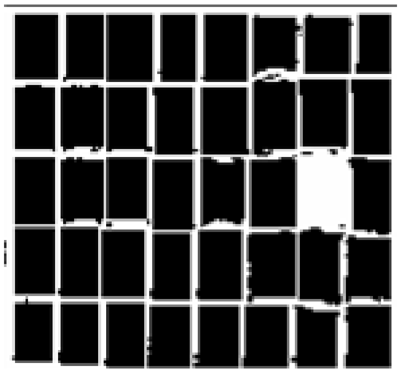


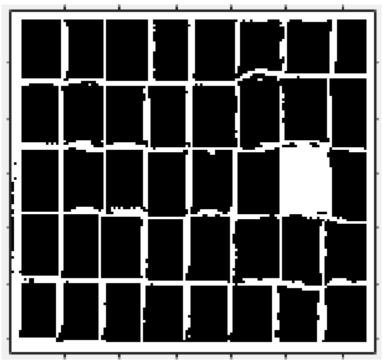
Figure 9: Silkworm cocoon image after open operation

4.2. Marking of connected areas of silkworm cocoon image

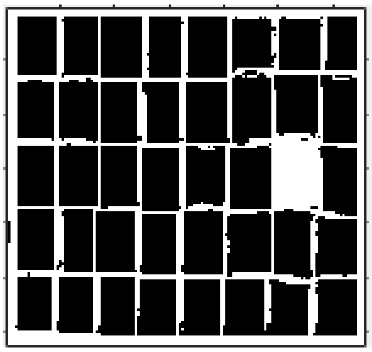
After the open operation of the silkworm cocoon image is executed, it must be marked with the connected area. Since the silkworm cocoon image after the open operation is a binary image, the mark of the connected area can be executed, and the eight-adjacent type is used in the text. Figure 9 shows the silkworm cocoon image after marking through the connected area. From the figure, it can be seen that, after the connected area is marked, all the outlines except the blood cocoon area are marked.

5. Performance test and comparison of segmentation algorithms for silkworm cocoons

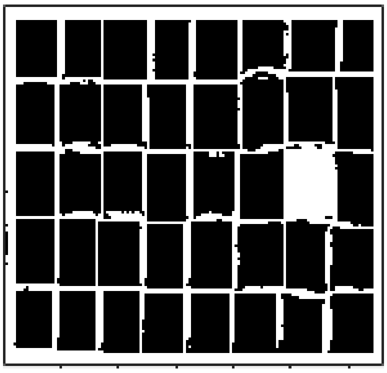
In order to verify the validity of the proposed visual segmentation algorithm (i.e. local threshold segmentation algorithm), some experiments are carried out, and the test results are compared with those of the histogram segmentation algorithm [7], OTSU segmentation algorithm [8] and iterative segmentation algorithm [9]. Fig.10 (a)-(d) is the segmentation results of four algorithms. From the figure, it can be seen that the performance of the local threshold segmentation algorithm is optimal. The segmented grid outline shape is closest to the original image outline. The local segmentation effect is good and it will not cause the target to be lost.



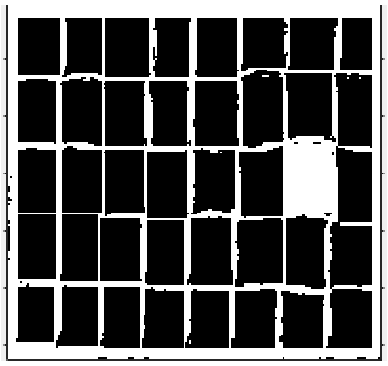
(a) Histogram segmentation



(b) OTSU segmentation



(c) Iterative segmentation



(d) Local threshold segmentation

Figure 10: Segmentation Images of four threshold algorithms

For the histogram threshold segmentation algorithm, its advantage is that the algorithm structure is relatively simple, but because it belongs to artificial threshold segmentation, it is necessary to continuously try and compare to determine the optimal threshold. The time cost is high and the algorithm efficiency is low. Moreover, for an image with a small gray scale difference between the background and the target object, the segmentation effect is not ideal. The iterative threshold segmentation algorithm is more complicated than the histogram threshold segmentation algorithm, but the segmentation algorithm has higher precision. In most cases, its segmentation effect is better than that of the histogram threshold algorithm. However, if the image is noisy, the segmentation effect is not as good as that of the histogram threshold segmentation. The OTSU automatic threshold segmentation algorithm is simple and runs fast, and its principle is to maximize the variance of the target and background gray scales, so that the segmentation effect is the best and the segmentation precision is very high. But like the iterative segmentation algorithm, its segmentation effect is poor for noisy images.

6. Conclusion

In order to solve the influence of factors such as illumination changes and background gray scales on the identification of silkworm cocoons during the automatic picking, a silkworm coco segmentation and localization algorithm based on local threshold and regional features was proposed. Through theoretical analysis and image processing results, the following conclusions can be drawn:

(1) The grayscale processing of the original silkworm cocoon image can effectively reduce the amount of calculation of subsequent processing;

(2) Grayscale enhancement is beneficial for subsequent image segmentation;

(3) The local threshold-based segmentation algorithm can effectively avoid target loss caused by different illumination changes and background grayscale;

The image processing results and performance comparison also verify that the proposed algorithm can accurately segment and locate the grid outlines in the silkworm cocoon images.

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