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Research on Threshold Segmentation and Hough Circle Detection Based on Grape Image

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Abstract: To solve the problem that the shape of the fruit is round and overlapping, the segmentation and circle detection of the image of the fruit are studied, which provides a feasible method for the recognition and positioning of the fruit by mechanical picking. In this paper, the image is first enhanced, Tsallis entropy algorithm and Ostu method are selected to find the best threshold for image segmentation, and Hough transform is combined to detect the target region automatically. By comparing the segmentation and detection effects of Tsallis entropy algorithm and Ostu method on grape images, the experimental results show that under the condition of the same radius and sensitivity of 0.96, the segmentation effects of the two algorithms are comparable, and the Ostu method correctly detects relatively more grape numbers. The proposed algorithm can effectively improve the detection and operation efficiency and reduce the calculation amount.

Key Words: Grape; Tsallis Entropy; Ostu Method; Threshold Segmentation; Hough Transformation

1 INTRODUCTION

The application of mechanical picking in the fruit industry is more and more extensive, and gradually realize the transformation from traditional manual picking to modern mechanical picking. In mechanical picking, image segmentation and target detection are the key to recognition and positioning of the fruit picking, so it is very important to have good segmentation effect and detect the target fruit correctly.

Grape image segmentation is an important task in recognition and image processing in mechanical picking. Its purpose is to extract and segment the image features that meet the needs. In recent years, scholars at home and abroad have done a lot of research in the field of image segmentation. For example, Fan Pan et al. [1] explored the RGB color space features of the gray center of the image, including halation and shadows, and achieved good segmentation effect at shadows and patches. The image segmentation model ASE-UNET [2] could achieve accurate segmentation of oranges in complex environments. In addition, Japanese scholar OTSU proposed the Ostu method, which seeks the optimal threshold for image segmentation according to the large difference in gray values, which is not affected by the contrast of brightness [3], has great practicability and small computational redundancy. Tsallis entropy image threshold segmentation [4] calculates image complexity, reduces image dimension and achieves good segmentation effect. It has certain advantages for image segmentation. Wang Zhifen et al. [5] proposed that segmentation based on SE-COTR (coordinate transformation) was suitable for the detection of target fruits of different sizes, but it required a large amount of calculation. Junxiong Liang et al. [6] achieved accurate segmentation in complex environments, but it was based on plant phenotype information only. While the segmentation effect of the lift image is still an unknown problem, the fine-tuned CNN(Convolutional Neural Networks) network [7] has high segmentation accuracy for various types of flowers, but requires a large number of experimental flower datasets and consumes a lot of time.

Positioning is extremely important in mechanical picking. The connected domain labeling method [8] is used for segmentation, followed by circle detection. The calculation is small and the detection efficiency of regular circles is high. Guichao Lin et al. [9] import arbitrary fragments of discriminant shapes for detection and reference, and use the new probabilistic Hough transform to gather subfragments. This method is competitive for the detection of most types of fruits in the natural environment, but it is difficult to identify the hidden fruit accurately for the large overlap of the fruit.

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Therefore, this paper selects suitable feature maps, analyzes Tsallis entropy algorithm and Ostu method, and compares the segmentation effects of the above two algorithms on the lifted image. Combined with Hough circle transform to detect the number of grape objects in the target region, effective segmentation and detection of the target lifted objects are realized, providing a feasible method for picking, identifying and locating the target grape objects.

2 Grape Image Preprocessing

2.1 Segmentation And Testing Workflow

Firstly, the collected grape images are enhanced to improve image quality, discernability and fidelity, etc. Tsallis entropy algorithm and Ostu method are respectively used to separate the enhanced images, combined with the principle of Hough circle transform, and finally, the renderings of the two segmentation algorithms are analyzed and a conclusion is drawn. The flow chart of segmentation and detection is presented in this paper. As shown in Fig. 1.

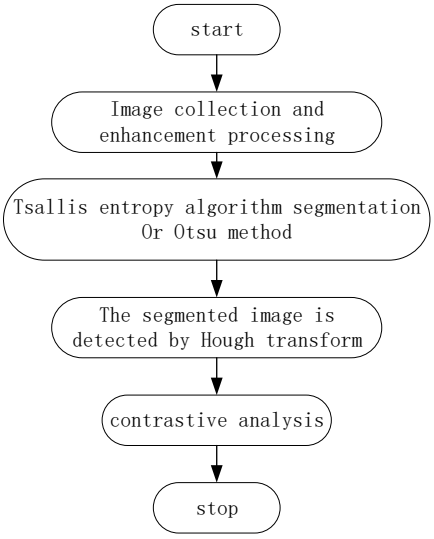

Fig. 1 Work Flow Chart

2.2 Image Enhancement Processing

In order to improve the quality and visual effect of the grape image, the grape image is converted to grayscale image first, and then the image enhancement process is completed after traversing every pixel of the image. The contrast and brightness of the image are enhanced, so as to improve the interpretation and recognition of the image, enhance the clarity of the image, and further lay the foundation for the subsequent work of image segmentation, as shown in Fig. 2

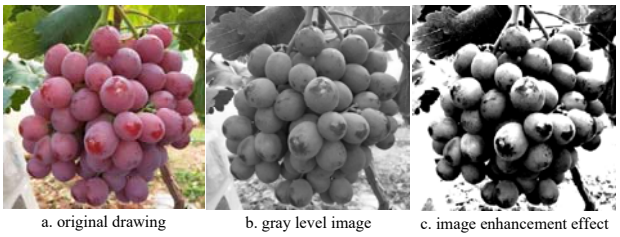

Fig. 2 Enhanced Processing Of Grape Image

Taking the Otsu method as an example, after image enhancement processing, compared with the original image segmentation, the segmentation of the background of the image has been weakened to a certain extent, such as leaves, branches, and land, and the segmentation of the target area of the image has been improved to a certain extent. The segmentation effect is better, and the fruit of the fruit is more clear, as shown in Fig. 3.

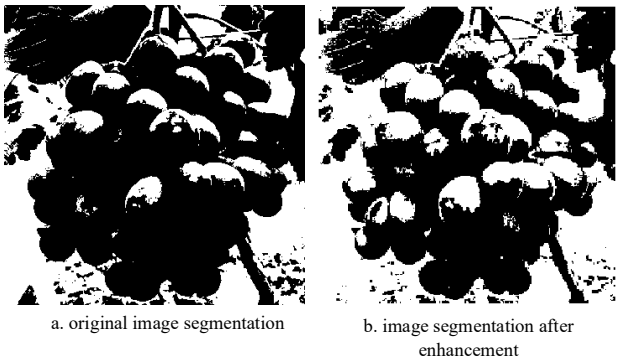

Fig. 3 Segmentation Comparison Between Original Image And Enhanced Processing

2.3 Experimental Environment

Lenovo Computer: The processor is AMD Ryzen 7 5700U with Radeon Graphics and clocked at 1.80 GHz. The operating system is 64-bit operating system, based on x64 processor, Windows 11 home Chinese version, the algorithm is carried out in MATLAB R2023a.

3 Segmentation Analysis Of Grape Image Thresholds

3.1 Tsallis Entropy Algorithm Analysis

Tsallis entropy algorithm, which is a gray-scale image segmentation method based on information theory, is widely used. For gray image, it can be regarded as a probability distribution function, assuming that the gray value of the image is L, and p is the probability of gray level i in the image. The threshold value t divides the image into target 0 and background 1, θ_0 and are θ_1 the gray probability of the target and

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background respectively, and q is the histogram mean of the reasonably selected segmentation image.

$$\theta_0 = \sum_{i=1}^{t} pi ; \quad (1)$$

$$\theta_1 = \sum_{i=t+1}^{L-1} pi ; \quad (2)$$

$$\theta_0 + \theta_1 = 1 ; \quad (3)$$

S_q^0 is the Tallis entropy of target 0, S_q^1 is the Tsallis entropy of background 1,

$$S_q^0 = \frac{[1-\sum_{i=1}^{t} (\frac{pi}{\theta_0})^q}{q-1} ; \quad (4)$$

$$S_q^1 = \frac{[1-\sum_{i=t+1}^{L-1} (\frac{pi}{\theta_1})^q}{q-1} ; \quad (5)$$

Tsallis total entropy S_q is

$$S_q = S_q^0 + S_q^1 + (1-q) S_q^0 S_q^1 . \quad (6)$$

The result of image segmentation according to the above formula and relation is shown in Fig. 4.In MATLAB software, under the condition that the histogram mean q of the segmentation image is 1.1, Tsallis entropy is used to select the threshold value, the threshold value is 0.5569, and the time is 0.2955s. The probability of target and background pixels is relatively equal. When the threshold is 0.5569, the target and background pixels are considered to be independent and related. According to the entropy threshold, the background and target of image pixels are divided. Compared with the Tsallis entropy segmentation effect, the original image retains more complete details, the image segmentation algorithm runs fast, and can complete the image processing task in a short time, which is highly practical. However, since Tsallis entropy automatically divides the threshold value into two categories: target 1 and background 2, when there are more black parts connected together, Not good for Hough circle detection.

a. original drawing b. Tsaiis entropy segmentation

FIG. 4EFFECT OF ORIGINAL IMAGE AND TSALLIS ENTROPY SEGMENTATION

3.2 *OSTU METHOD*

The Ostu method uses the inter-class variance of gray histogram to determine the optimal threshold, and divides the image into two parts: target and background. By traversing all possible thresholds, the core calculates the inter-class variance corresponding to each threshold, and maximizes the inter-class variance to ensure the minimum segmentation error. The greater the inter-class variance, the greater the difference between the target and the background image, the better the segmentation effect, and the image brightness and contrast have little influence on the image segmentation. Compared with the background image, the color of the grape is darker, which can effectively separate the target grape from the background.

Suppose that the gray value of the image is L, the threshold value is t, γ_0 and γ_1 are the two types of pixels separated by the threshold value t, M_0 represents the gray mean of class γ_0, M_1 represents the occurrence probability of class γ_1, and M_t represents the gray mean of the whole image. Traverse the entire lifting image and find the appropriate threshold t, so the class variance image of image σ_b^2 is:

$$\sigma_b^2 = \theta_0 (M_0 - M_t)^2 + \theta_1 (M_0 - M_t)^2 ; \quad (7)$$

In formula (7), θ_0 is the occurrence probability of class$\gamma_0$of the image, and θ_1 is the occurrence probability of class γ_1 of the image. When the gray value of the image is [0,L-1], when σ_b^2 reaches the maximum value, the optimal threshold is taken. In MATLAB software, the imhist function is used to calculate the histogram. According to the above calculation, when the gray level is greater than the optimal threshold, the image is displayed as white; when the gray level is less than the optimal threshold, the image is displayed as black. The effect after image segmentation is shown in Fig. 5.Under the current conditions, the optimal threshold is 136, the occurrence probability of class γ_0 is 0.7841, the occurrence probability of class γ_1 is 0.2159, the time is 0.1607s, the segmentation effect is better, the running time is shorter, etc.

a. original drawing b. Otsu method segmentation effect

FIG. 5 SEGMENTATION EFFECT OF ORIGINAL IMAGE AND OSTU METHOD

4 IMAGE SEGMENTATION COMBINED WITH HOUGH TRANSFORM DETECTION ANALYSIS

Hough transform extracts features by analyzing the shape of the image, such as circle, oval, straight line, etc. The algorithm

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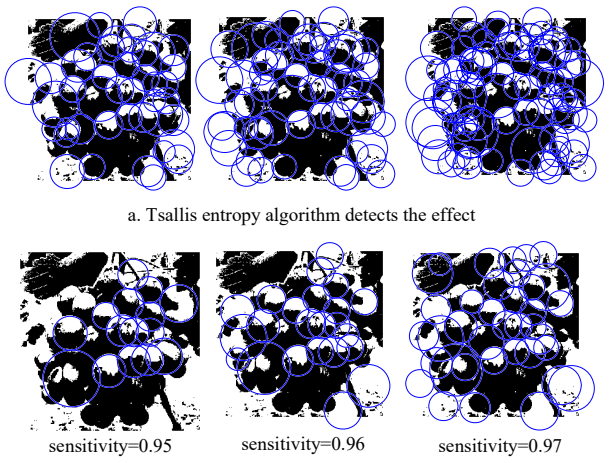
based on the circular Hough transform (CHT) finds the circle and its parameter radius and center in the image. Hough transform algorithm detects shapes in an image by mapping points in the image space to curves in the parameter space.

The construction parameters are a curve of the center coordinate (x_0, y_0) and radius r, so the equation of the circle is $(x - x_0)^2 + (y - y_0)^2 = r^2$, and the expression in polar coordinate system is $\begin{cases} x_0 = x - r\cos\theta \\ y_0 = y - r\sin\theta \end{cases}$.

In this paper, Hough circle detection is carried out after image segmentation. After image is converted into binary image in MATLAB platform, imfindcircles, a function of toolbox, is used for circle detection. The two-stage method used to calculate the accumulator array can effectively reduce the amount of computation and improve the efficiency of Hough a transform, which is mainly divided into pre-processing stage and Hough transform stage. The pre-processing stage mainly preprocesses images to reduce noise and interference, improve the accuracy of Hough transform, and provide the basis for the subsequent Hough transform. Hough transform maps the edge points in the image to the parameter space, calculates the corresponding curves of each parameter to form an accumulator, finds the local maximum value in the accumulator array, and the corresponding parameter is the shape detected in the image.

According to the expected size of the lift shape, the same radius is set to control the search range of the parameter space, and the sensitivity is adjusted to achieve faster running speed and higher detection efficiency of the lift. As the sensitivity increases, imfindcircles will detect more raised objects, but increasing the value of the sensitivity will lead to the risk of false detection. When the sensitivity is 0.96, the lift detection can take into account both high accuracy rate and low error detection rate. In this study, the sensitivity of Hough transform is 0.96, as shown in Fig. 6.



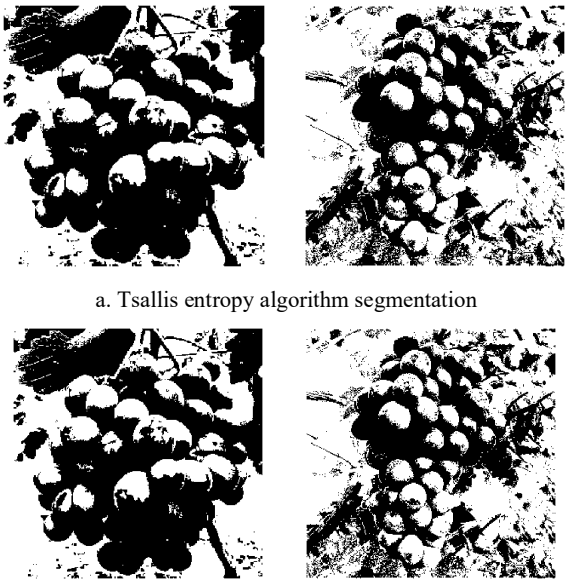
a. Tsallis entropy algorithm detects the effect

b.Otsu method was used to detect the effect

FIG. 6 DIFFERENT SENSITIVITIES OF THE TWO SEGMENTATION METHODS

5 EXPERIMENTAL RESULTS AND ANALYSIS

In order to verify the feasibility of Tsallis entropy algorithm, Ostu method combined with Hough circle transform to detect the lift, the lift image was enhanced and the related algorithm was tested. The feature map is selected and tested by the above relational algorithm. The two methods are segmented according to the threshold value to obtain the segmented image, as shown in Fig. 7.

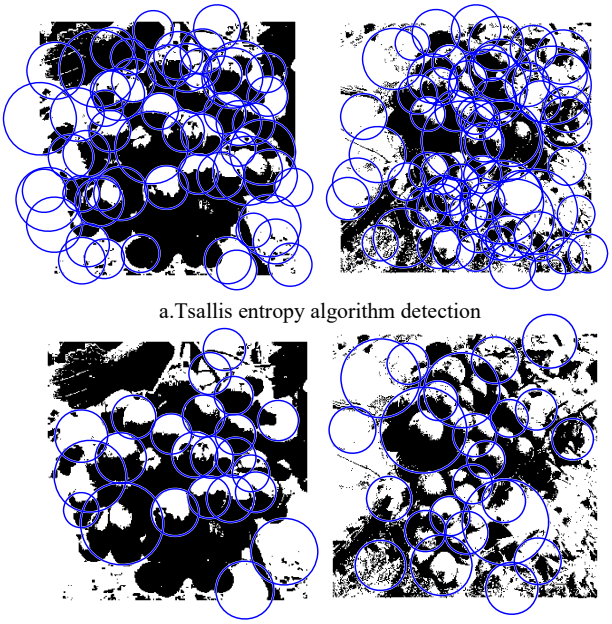


a. Tsallis entropy algorithm segmentation

b. Otsu method segmentation

FIG. 7 SEGMENTATION BETWEEN TSALLIS ENTROPY ALGORITHM AND OTSU METHOD

Figure (a) and Figure (b) are segmentation and comparison after enhanced processing. The segmentation effect of the two algorithms is roughly the same, which enhances the clarity of segmentation of the fruit, improves the accuracy of circle detection, and is conducive to Hough circle detection. However, the complexity of Tsallis entropy calculation is relatively high, and the complexity of image gray level is relatively high, so the algorithm may not be able to segment the ideal segmentation effect. Figure 4 shows the segmentation effect without enhancement processing, and the detail retention is not very complete. However, the Ostu method is simple to calculate, and can also segment effectively when the image histogram is bimodal and there is only small noise.



a.Tsallis entropy algorithm detection

b. Otsu method detection

FIG. 8 TSALLIS ENTROPY ALGORITHM AND OSTU METHOD

When the same radius range and sensitivity are set in Hough algorithm, the two algorithms detect a large number of grape, as shown in Fig. 8. The detected numbers in Figure (a) algorithm are 58 and 64 (from left to right) respectively, and the detected numbers in Figure (b) algorithm are 23 and 24 respectively. Under the current conditions, the accuracy of the detected numbers is also reflected, ignoring the detected numbers of leaves, branches and interference background, and the correct number of detected lifts is more, and the results show that the detection deviation is small. However, leaves and interference background are detected as circles in segmentation images.

According to the analysis in Figure 7 and 8, under the condition of the same radius and sensitivity of 0.96, the two segmentation effects are comparable, and the Tsallis entropy algorithm has good practicability, automatically adapt to threshold selection for segmentation, and has a large number of detections but a large number of errors, while the Ostu method correctly detects a relatively large number of picks. When the area of the connected domain divided by the two algorithms is large, there is a case of missing detection.

6 CONCLUSION

In order to verify the segmentation effect of Tsallis entropy algorithm and Ostu method on grapes and the feasibility of Hough circle transform to detect the number of grapes, this paper enhanced the grapes image, and then used the two algorithms combined with Hough circle transform to detect grapes. Under the condition that the radius is the same and the sensitivity is 0.96, the segmentation effect of the two algorithms is similar. According to the above, segmentation methods can be selected according to different image quality and complexity. The Tsallis entropy algorithm detects a large number of number and a large number of errors, while the Ostu method correctly detects a relatively large number of number. In this paper, two kinds of segmented images are used to carry out Hough transform, which can effectively improve the detection and operation efficiency, reduce the calculation amount, and the algorithm is effective and reliable. Since there may be unobserved variables and measurement errors in the experiment, there will be unavoidable errors and deficiencies. On this basis, deep learning will be used in the future to provide a feasible method for mechanical pickling in the future.

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