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Chinese wolfberry selection grading system based on MATLAB image processing

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Abstract

In view of the problems such as small size, difficult to distinguish color and difficult to grade quantity, the paper puts forward the processing of the acquired image by MATLAB image processing technology, and obtains the aspect ratio, area and color characteristics of wolfberry. The smallest external rectangle found can efficiently and accurately extract the aspect ratio characteristics of radon, the average total image processing time of a single image is 0.51879s, the average recognition rate of multiple granules is 100%, and the average recognition rate of special, first and second grade products respective is 86.78%, 87.77% and 82.29%. Combined with the MATLAB GUI development toolbox, the design of the selection grading system is completed, and the system is simple to operate and improves the grading efficiency to a certain extent. Through repeated design and verification, the system is efficient and reliable, which can provide some reference for other product grading in engineering.

Keywords

Wolfberry; Evaluation index; Minimum enclosing rectangle; GUI; Classification system.

1. Introduction

Wolfberry is one of the important nutritious foods in China, and the wolfberry products are mainly dried fruits [1, 2]. Nowadays, while the demand for wolfberry is increasing in China, there are also many problems in the market. For example, a variety of brands of the same product in a region have chaotic appearance and uneven quality of wolfberry products [3]. Because of the long picking cycle of lycium barbarum, the color and size of finished product of lycium barbarum were confused due to different planting conditions and drying conditions in the drying process, resulting in the difficulty of grading lycium barbarum.

At present, the classification of lycium barbarum is mostly visual classification, which has randomness, uncertainty and other factors. In the field of fruit classification, image processing technology is mainly based on large, single, approximately round fruit. For example, Wang Yujie [4] discussed the image processing method of Apple classification through image processing technologies such as pre-processing, image sharpening and image segmentation, and verified the accuracy of automatic classification method of machine recognition. Zhang Yajing, Deng Lie et al. [5] used image analysis technology to extract the characteristics of citrus number, total circumference and total area, and obtained the correlation coefficient between citrus number and individual plant parameters. Chen Linlin, Jiang Daqing et al. [6] completed the classification of pitaya's size and color by using machine vision technology. In the classification field of Lycium barbarum, Wang Lutcheng and Tan Junmei [7] et al. used digital image processing technology to extract the color, size and shape characteristics of lycium barbarum from the lycium barbarum image, and clustering the features with K-means algorithm to obtain the benchmark of the corresponding grade of lycium barbarum, but did not establish the control structure of machine vision system. Yi Weiguo, Zhang Dong et al. [8] preprocessed the

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wolfberry image with image processing technology, and obtained the transverse and longitudinal diameterof wolfberry by using ellipse fitting algorithm. However, the classification of wolfberry shape by area index was lacking in the analysis of the size and shape basis of wolfberry.

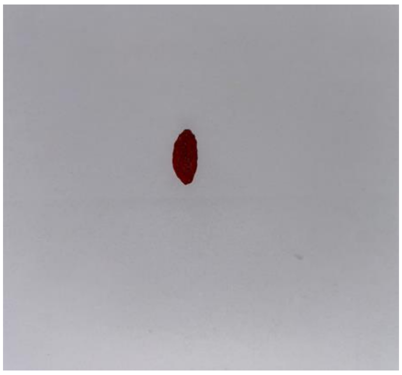
Zhang 'o shan [9] and others of digital image processing based on MATLAB tools of Chinese wolfberry image processing, access to the area of the Chinese wolfberry size and color features, according to the filling broken, oil grain parts contour area accounted for the proportion of the whole Chinese wolfberry area judgment and classification processing, this method can to nondestructive testing of Chinese wolfberry, but in the classification standard is not perfect, The effects of transverse diameter and longitudinal diameter on the quality of Lycium barbarum were not considered. These abundant research results provide a verifiable basis for the study of objects with irregular shape, large number and small volume. Wolfberry grading is rarely studied in the field of MATLAB image processing, especially in the field of sorting and grading of many wolfberry seeds whose colors are difficult to distinguish.

In this paper, the size, quantity, color and width to length ratio of wolfberry samples were extracted by MATLAB image processing technology to further judge the quality of wolfberry. Relying on the Guide toolbox in MATLAB, a system interface was developed to select and grade Wolfberry. The interface has the advantages of good human-computer interaction and simple operation. For the enterprise staff of wolfberry grading work to improve efficiency, reduce human and material resources, improve the core competitiveness of enterprises.

2. Experimental materials, instruments and image processing

2.1. Experimental materials and instruments

The experimental materials are medlar, vernier caliper, camera and experiment box. 300 lycium berries were randomly selected for image collection, the image number is A001-A300, and then 24, 25, 26, 27, 28, 29 were randomly selected from the 300 lycium berries for image collection, the image number is B001-B006. In the experiment, static images were taken. Firstly, the wolfberry pellets to be detected were placed at the bottom of the experimental box, and the distance between the wolfberry pellets and the camera was 15cm. Because wolfberry contains sugar and a small amount of water, if the detection of many wolfberry grains is easy to stick together, so the wolfberry grains should be separated to avoid overlapping wolfberry grains, resulting in interference for the image processing behind, reduce the recognition rate. A total of 306 images were collected in the experiment. Figure 1 shows the original image of lycium barbarum. Fig. 1 (a) shows the original image of single lycium barbarum and Fig. 1 (b) shows the original image of multiple lycium barbarum.



a) Original image of a single wolfberry grain b) Original images of many wolfberry grains

Fig. 1 Original image of wolfberry

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2.2. Image processing

MatlabR2016a software was used to program the collected images to extract wolfberry targets and corresponding data. First of all, the collected wolfberry images were read, calling function imread, and the collected images were generally three channel color images. In order to better subsequent processing, the color images were grayed, calling function rgb2gray, and then the gray level images of Wolfberry were further converted into binary images, calling function im2bw. When calling this function, it is necessary to find its optimal threshold level, and the value of Level can be directly calculated by the function Graythresh. Fig. 2 (b) is the binary image with level 0.3725, and then the binary image is inversely processed. The calling function format is BW1=~BW, and finally the inverted image in Fig.2 (c) is found. In particular, there are black dots in the target area, so the image after inverse processing is processed and then closed operation is carried out. The call function is imclose, and the call format is BW2 = imclose (BW1,se). Before calling this function,se is required, and se is obtained by strel function. The call format is se=strel('disk',r), in this program r=3 processing effect is optimal. Through the image processing of Wolfberry, the precise target of wolfberry in the image was obtained, as shown in Fig. 2 (d).

a) Grayscale image b) Binary image c)Inverse processing d) Closed operation processing

Fig. 2 Image processing result of feature extraction of Chinese wolfberry

3. Extraction of target characteristic parameters of Lycium barbarum

3.1. Extract the width-length ratio of Lycium barbarum

The shape of wolfberry can be regarded as oval, so it can be represented by the ratio of width to length. The length and width of equivalent wolfberry grain were obtained by calculating the minimum enclosing rectangle of wolfberry grain. The larger the width to length ratio of wolfberry grain, the rounder its shape, conversely, the smaller the width to length ratio of wolfberry grain, the more slender its shape. At present, algorithms for solving the minimum enclosing rectangle include rotation algorithm, scanning algorithm, vertex chain code algorithm, etc. [8, 10], while Cao Yuanwen [11] et al. conducted a comparative study on the shape characteristics of aggregate particles by optimizing the convex shell boundary rotation algorithm, and realized the rapid calculation of the flattening rate of particles through example verification and analysis.

The basic steps of the convex shell boundary rotation algorithm include determining the convex shell boundary value, rotating the convex shell boundary and calculating the minimum enclosing rectangle.

Determine the convex shell boundary value:

The maximum value in X axis direction and minimum value in Y axis direction of convex shell boundary are taken as the initial minimum enclosing rectangle of boundary rotation, and the initial minimum enclosing rectangle area and the maximum and minimum coordinates on the boundary are recorded.

The convex shell boundary is rotated:

The included Angle α_i of each boundary line segment on the convex hull boundary is determined. Calculate the included Angle of each boundary line segment on the convex shell boundary relative to the X direction counterclockwise, and the rotation Angle can be calculated as follows:

$$\theta_i = acrtan\left(\frac{y_{i+1} - y_i}{x_{i+1} - x_i}\right) \tag{1}$$

Where θ_i is the rotation Angle of the i-th line segment of the convex shell boundary, $x_i$and y_i are the horizontal and vertical coordinates of the i point of the convex shell boundary respectively, $x_{i+1}$and y_{i+1} are the horizontal and vertical coordinates of the i+1 point of the convex shell boundary respectively.

The convex hull boundary rotates clockwise around the origin of coordinates in accordance with the rotation angles θ_1、θ_2、θ_3、 ⋯ 、θ_i. For point rotation transformation in the same coordinate system, the rotation coordinate formula is derived as follows:

$$x_i = r\cos\alpha_i \tag{2}$$

$$y_i = r\sin\alpha_i \tag{3}$$

$$x_i' = r\cos(\alpha_i - \theta_i) = r\cos\alpha_i\cos\theta_i + r\sin\alpha_i\sin\theta_i \tag{4}$$

$$y_i' = r\sin(\alpha_i - \theta_i) = r\sin\alpha_i\cos\theta_i - r\cos\alpha_i\sin\theta_i \tag{5}$$

$$x_i' = \cos\theta_i x_i + \sin\theta_i\, y_i \tag{6}$$

$$y_i' = \cos\theta_i y_i - \sin\theta_i\, x_i \tag{7}$$

$$(x_i' \quad y_i')^T = \begin{pmatrix} \cos\theta_i & \sin\theta_i \\ -\sin\theta_i & \cos\theta_i \end{pmatrix} * \begin{pmatrix} x_i \\ y_i \end{pmatrix} \tag{8}$$

Where, $x_i'$and y_i' are respectively the horizontal and vertical coordinates of the ith point rotated on the convex shell boundary, and α_i is the included Angle of the ith line segment on the convex shell boundary relative to the X-axis direction.

Will rotate after the convex hull of a maximum of boundary on the X axis and Y axis direction of the minimum as external rectangle boundary after rotation, the rotation calculation of external rectangle area, and compared with the initial minimum circumscribed rectangle area, preserving external rectangular area of the minimum circumscribed rectangle four vertex coordinates and rotation Angle, and in the area of the minimum circumscribed rectangle shown in the image. Then the convex shell boundary with an outer rectangle is rotated back at the same rotation Angle, and the inverse coordinate formula is:

$$(x_i'' \quad y_i'')^T = \begin{pmatrix} \cos\theta_i & -\sin\theta_i \\ \sin\theta_i & \cos\theta_i \end{pmatrix} * \begin{pmatrix} x_i' \\ y_i' \end{pmatrix} \tag{9}$$

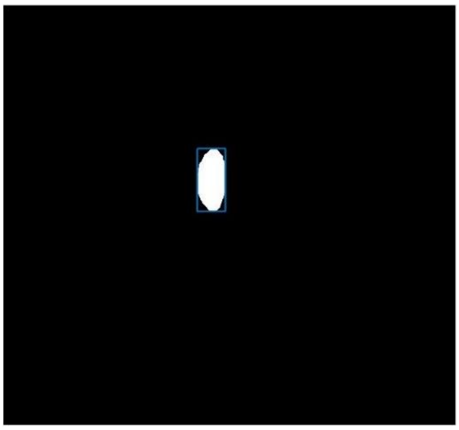
Where, $x_i''$and y_i'' are respectively the horizontal and vertical coordinates of the ith point on the convex shell boundary after inverse rotation.

wolfberry initial position and horizontal X-axis into θ Angle, determine the boundary value of Chinese wolfberry grain, black rectangle for the initial minimum circumscribed rectangle of medlar, will Chinese wolfberry along the clockwise around the origin of coordinates to the horizontal position for the external rectangle, then put the Chinese wolfberry in the same rotation Angle reverse rotation to the initial position. Among them, the solid green line is the rotation track line of Lycium barbarum, the blue rectangle is the external rectangle of lycium barbarum obtained after continuous rotation, and the red rectangle is the minimum external rectangle of lycium barbarum after inverse rotation.

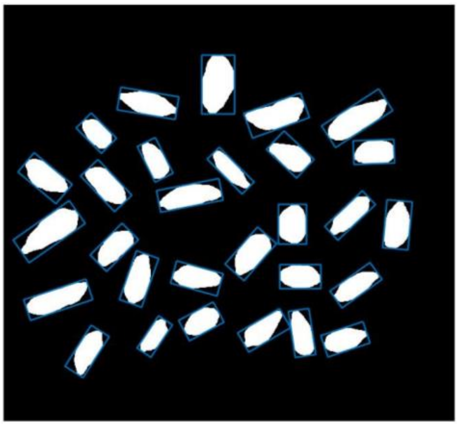
Calculates the minimum enclosing rectangle

Convex hull boundary with rotation Angle, θ_1、θ_2、θ_3、 ⋯ 、θ_i to repeat the order of rotation, the rotation if the external rectangle area is less than the previous one external rectangular area, will retain the current external rectangular area, four vertex coordinates and rotation Angle, rotation is finished until all boundaries, one of the smallest rectangle for the minimum circumscribed rectangle, The smallest enclosing rectangle is connected sequentially by four vertex coordinates.

Fig.3 shows the minimum enclosing rectangle of wolfberry grain. Where, 4A) is the minimum enclosing rectangle of single wolfberry grain with image number A002, and 4b) is the minimum enclosing rectangle of multiple wolfberry grain with image number B06.



a）The minimum enclosing rectangle of a single wolfberry grain



b）The smallest enclosing rectangle of many wolfberry grains

Fig. 3The smallest circumscribed rectangle of wolfberry grains

3.2. Extract the area value of lycium barbarum

An image is composed of pixels. As long as the real area represented by each pixel is calculated, the real area can be calculated according to the number of pixels [12]. MATLAB image processing technology in the regionprops function can calculate the number of pixels in the image medlar.

The calculation formula is:

$$S = \frac{S_0 * W_1}{W_0} \tag{10}$$

Where S0 is the actual area of the reference, W1 is the total number of pixels of lycium barbarum, W0 is the total number of pixels of the reference. Fig. 4 shows the pixel number of Lycium barbarum and its reference. On the left is the reference with the actual area S0= 1cm^2(0.39 in), and its pixel number W0=2241; on the right is the lycium barbarum with the pixel number W1=1991. Therefore, the actual area of the lycium barbarum can be calculated according to the formula.

Fig. 4 Number of pixels of wolfberry and reference

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3.3. Extract the chroma value of wolfberry

The color feature extraction of images is generally RGB model, HSI model and HSV model. In the research field of MATLAB image processing on Wolfberry, RGB model and HSI model are commonly used. As RGB model can not well adapt to the actual situation of human interpretation of color, HSI model is more consistent with human description and interpretation of color objects than RGB model [13]. RGB model is associated with HIS model. H, S and I values of the image can be calculated after R, G and B values of the image are found. The formula for transforming RGB model into HIS model is as follows:

$$\mathrm{H} = \begin{cases} \theta, & B \le G \\ 360 - \theta, & B > G \end{cases} \tag{10}$$

$$\theta = \arccos\left\{\frac{[(R-G)+(R-B)]/2}{[(R-G)^2+(R-G)*(G-B)]^{1/2}}\right\} \tag{11}$$

$$\mathrm{S} = 1 - \frac{3}{(R+B+G)}[min(R,G,B)] \tag{12}$$

$$\mathrm{I} = \frac{1}{3} * (R+G+B) \tag{13}$$

The color information of the image has nothing to do with the I component in the HSI color space, and the way people perceive the color of objects is closely related to the H and S components [14]. Therefore, in order to better characterize the color of wolfberry, the experiment used the hue (H) and saturation (S) in HIS model to reflect the wolfberry.

4. Example verification and analysis

In Fig. 5, the maximum width and maximum length of wolfberry grains were measured with vernier calipers. MATLAB program was used to extract the area, R, G and B values of a single wolfberry kernel, and verified with Photoshop image processing software, the results were consistent. Therefore, this paper will focus on the use of MATLAB programming extracted parameter values for analysis.

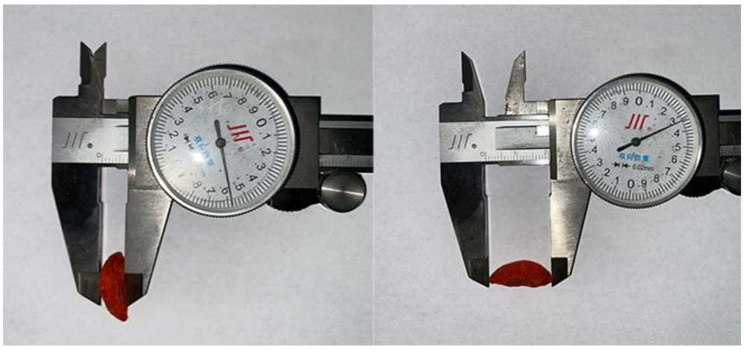

Fig. 5 Vernier calipers measure the maximum length and width of wolfberry

4.1. The data analysis

The width to length ratio, area and chroma of the smallest surrounding rectangle of single Wolfberry kernel with image number a001-A300 were obtained respectively. Table 1 shows the comparison of the mean width to length ratio calculated by manual measurement method with vernier caliper and minimum enclosing rectangle method. Table 2 shows the mean area of a single sample of Wolfberry grain.

Table 1 Comparison of the manual measurement of the average value of the aspect ratio with the average value of the measured aspect ratio in this paper

Number of samples of	Image number	Mean value measured in	Manually measured	The relative	Relative error rate

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Wolfberry		this paper	mean	error	
5	A001-A005	0.550297	0.625	0.0747	11.95%
10	A001-A010	0.504545	0.573	0.0684	11.94%
20	A001-A020	0.482023	0.529	0.0469	8.89%
40	A001-A040	0.482274	0.509	0.0267	5.25%
80	A001-A080	0.501951	0.517	0.015	2.91%
160	A001-A160	0.509722	0.521	0.0113	2.16%
300	A001-A300	0.518000	0.528	0.01	1.89%

Table 2 Average area of wolfberry grain samples

Number of samples of Wolfberry	Image number	Average area / cm^2
5	A001-A005	1.2315(0.1873 in^2)
10	A001-A010	1.2251(0.1863 in^2)
20	A001-A020	1.2046(0.1832 in^2)
40	A001-A040	1.1103(0.1688 in^2)
80	A001-A080	1.0339(0.1572 in^2)
160	A001-A160	0.9356(0.1423 in^2)
300	A001-A300	0.8587(0.1306 in^2)

Table 1 shows the relationship between the sample number of Lycium barbarum and the mean aspect ratio measured by different methods. With the increase of the number of tested samples, the width-to-length ratio measured by the minimum enclosing rectangle method decreased first and then increased, and the width-to-length ratio measured by the manual vernier caliper also decreased first and then increased. In general, the mean measured by the minimum enclosing rectangle method is slightly smaller than that measured by manual method. Relative artificial measure method, the maximum error is 11.95%, the minimum is 1.89%, with the increase in the number of Chinese wolfberry sample size detection, minimum circumscribed rectangle method relatively, in turn, reduce the artificial method of measurement error, so in Chinese wolfberry grain samples were more cases, minimum circumscribed rectangle method is used to measure the width of the long than is relatively close to the manual measurement. Table 2 shows the mean area of the tested samples of Wolfberry seeds. As the number of samples increased, the mean area of samples decreased. When the maximum number of samples was 300, the mean area of samples was 0.8587 cm^2 (0.1306 in^2).

4.2. Medlar seed selection grading system

Fig.6 shows the sorting and grading system of Wolfberry seeds. With the help of MATLAB Guide toolbox, an efficient human-computer interaction interface has been developed. The interface by clicking the open button to read the pictures and click grading button to calculate, according to gray level image processing, image binarization processing, take the processing image and closing operation processing images, and using the minimum circumscribed rectangle image tag count for more than Chinese wolfberry grain through calculate the area of the Chinese wolfberry capsule and longer than wide selection of classification standard and combined with the above. Finally, the total number of lycium barbarum, the number of special lycium barbarum, the number of first-class lycium barbarum, the number of second-class lycium barbarum and the calculation time were shown.

Fig.6 shows the sorting and grading of multiple wolfberry seeds with image number B06. It can be seen that the total number of wolfberry grains is 29, among which, the high-grade wolfberry grains are 6, the first-class wolfberry grains are 14, the second class wolfberry grains are 9, and the total time is 0.50402s. In order to verify the feasibility of the automatic sorting and grading system of Wolfberry seeds, the images numbered B01, B02, B03, B04, B05 and B06 were manually and automatically graded, and the results were compared as shown in Table 3.

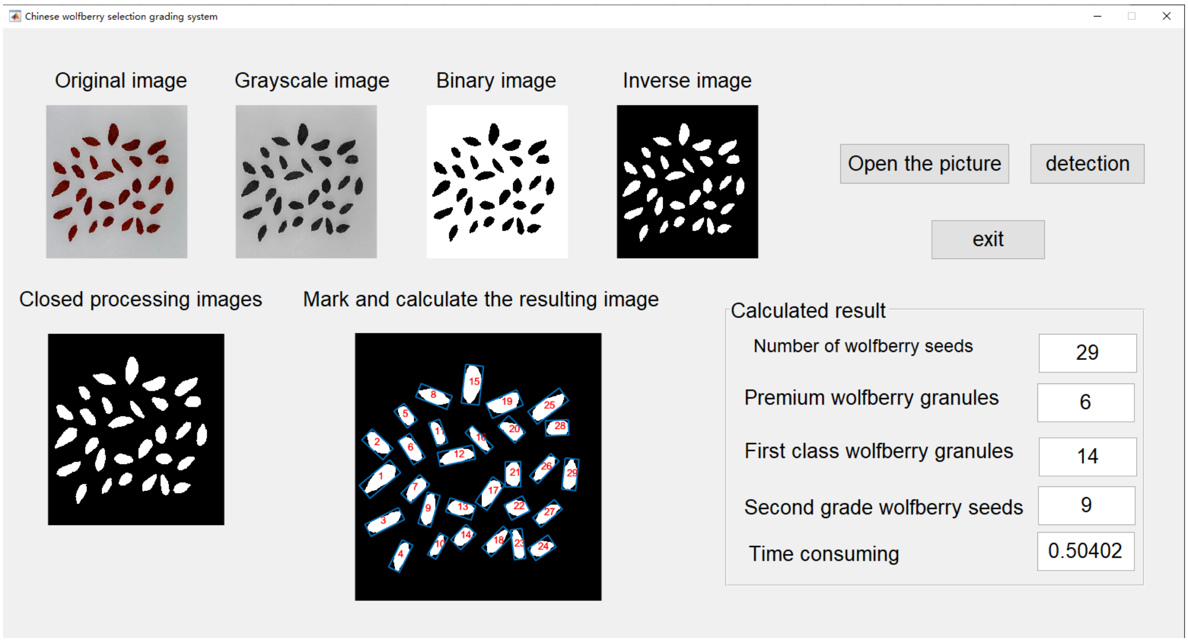

Fig. 6 Wolfberry grains featured grading system

Table 3 Comparison of manual grading and automatic grading

Image number	Total number			super			First class			Second class			The total time consuming /s
	Artificial	Algorithm	Mean recognition rate	Artificial	Algorithm	Mean recognition rate	Artificial	Algorithm	Mean recognition rate	Artificial	Algorithm	Mean recognition rate	
B01	24	24		3	3		12	14		9	7		0.50804
B02	25	25		4	5		14	12		7	8		0.50235
B03	26	26	100%	4	3	86.78%	13	16	87.77%	9	7	82.29%	0.49367
B04	27	27		5	4		16	16		6	7		0.50165
B05	28	28		5	5		17	15		6	8		0.51987
B06	29	29		7	6		12	14		10	9		0.58717

As can be seen from Table 3, the average recognition rate of the automatic classification system for the number of Wolfberry seeds is 100%, the average recognition rate of wolfberry premium products is 86.78%, the average recognition rate of wolfberry first-class products is 87.77%, the average recognition rate of wolfberry second-grade products is 82.29%, and the average total time is 0.51879s.

5. Conclusion

Matlab image processing technology was used to extract the wolfberry target, extract the characteristic parameters of the wolfberry sample, compare and analyze the data results, establish a feasible automatic selection classification standard of Wolfberry, and draw the following conclusions:

(1) The minimum enclosing rectangle method was compared with the width/length ratio measured by manual vernier caliper, and it was found that the more the number of wolfberry grain samples, the smaller the relative error rate, so the minimum enclosing rectangle method can be used to measure the width/length ratio to represent the appearance characteristics of Wolfberry.

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(2) Extracting the ratio of width to length, area and average chroma of wolfberry seeds, and establishing the GUI interface of the sorting and grading system of wolfberry seeds, the system can be used as an assistant when the color difference of multiple wolfberry seeds is not obvious or it is difficult to select and grade multiple wolfberry seeds.

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