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Strawberry Fruit Identification and Ripeness Discrimination under Multi-Color Model

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Abstract:

Aiming at the problem of inaccurate fruit recognition and ripeness judgment of strawberries in natural environment due to lighting and shading, a method of strawberry fruit recognition and ripeness discrimination under multi-color model is proposed. The method firstly fuses segmented images of YCrCb, Lab and HLS color models, secondly separates strawberries one by one using the watershed algorithm, then uses the Hough transform to locate strawberries, and finally judges whether strawberries are ripe by comparing all fruit and ripe fruit data. The experiments show that the method achieves 93.6% recognition success rate for elevated strawberries and 93.25% accuracy for green-ripe and red-ripe strawberries.

Keywords*:Strawberry fruit identification,Color model,Ripeness discrimination,Watershed algorithm, Hough circle transform.*

I. INTRODUCTION

With the development of smart agriculture, technologies such as image recognition and target detection are widely used in agricultural production work. The application of image technology to fruit picking has become an important element to improve the efficiency of modern agricultural production.

Fruit identification and ripeness determination in natural environments are full of challenges, such as complex growth environments, changes in light intensity, and shading of fruits. The inaccuracy of fruit identification and ripeness judgment due to light and shading in natural environments has been studied by many scholars at home and abroad for such problems. XieZhiyong et al.[1] proposed to realize ripe strawberry recognition by a-channel image and Hough transform of Lab color model; Yan Yong et al.[2] proposed to recognize strawberry by gradient Hough transform under Lab color model. All of the above are traditional image processing methods based on color space and Hough circle transform, which are less computationally intensive, have lower hardware requirements, and can achieve recognition success rates of about 92% in specific scenes[3-6], but are less adaptable to changing environments.

In addition to traditional image processing methods, there are also fruit recognition and ripeness determination methods through machine learning. Ling Zhao et al.[7] used BP neural network for judging the ripeness level of strawberries; S. Anraeni et al.[8] recognized the ripeness of strawberries based on RGB

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feature extraction and K-NN algorithm; Besides, there are some deep learning methods such as using YOLO[9-11], CaffeNet[12], Mask R-CNN[13-17], and MobileNet[18] and other deep learning frameworks for fruit recognition and ripeness determination. The methods based on machine learning and deep learning have good recognition effects on fruit recognition and ripeness judgment in complex environments such as overlapping, occlusion, and dense, but these methods require a large number of images for training, have high hardware requirements, and are not suitable for embedded recognition devices.

To address the above problems, this paper proposes a method for strawberry fruit recognition and ripeness discrimination under multi-color model for improving the success rate of strawberry fruit recognition and ripeness judgment under natural environment.

The method is based on the traditional image processing method for strawberry fruit images in multi-color space, which has certain adaptability for light changes and judgment ability for fruit shading, and effectively improves the success rate of strawberry fruit recognition and ripeness judgment.

II. RESEARCH METHOD

This paper presents a method for strawberry fruit identification and ripeness discrimination under multi-color model.

The method is mainly divided into four processing steps: image pre-processing, fruit segmentation, target extraction and determination of fruit ripeness, as shown in Fig 1.

The specific work flow is as follows:

First, separate the strawberry fruit from the environment.

Combining the segmented images of lab-a channel and YCrCb CR channel with HLS multi-channel threshold segmentation image, the mask images of all strawberries are obtained, and then the strawberry fruit is segmented effectively.

Secondly, locate each strawberry fruit.

The watershed algorithm is used to segment the strawberry fruit individually, and the minimum circumscribed constraint Hough circle transform is proposed to fit and locate each strawberry fruit and identify the strawberry fruit.

Finally, judge whether the strawberry is mature.

Compare the mature strawberry area with all strawberry fruit areas. The area without coincidence is the immature strawberry area. Then calculate the relationship between the fitting center of strawberry fruit and the contour of a single strawberry, and record the position of mature and immature fruit.

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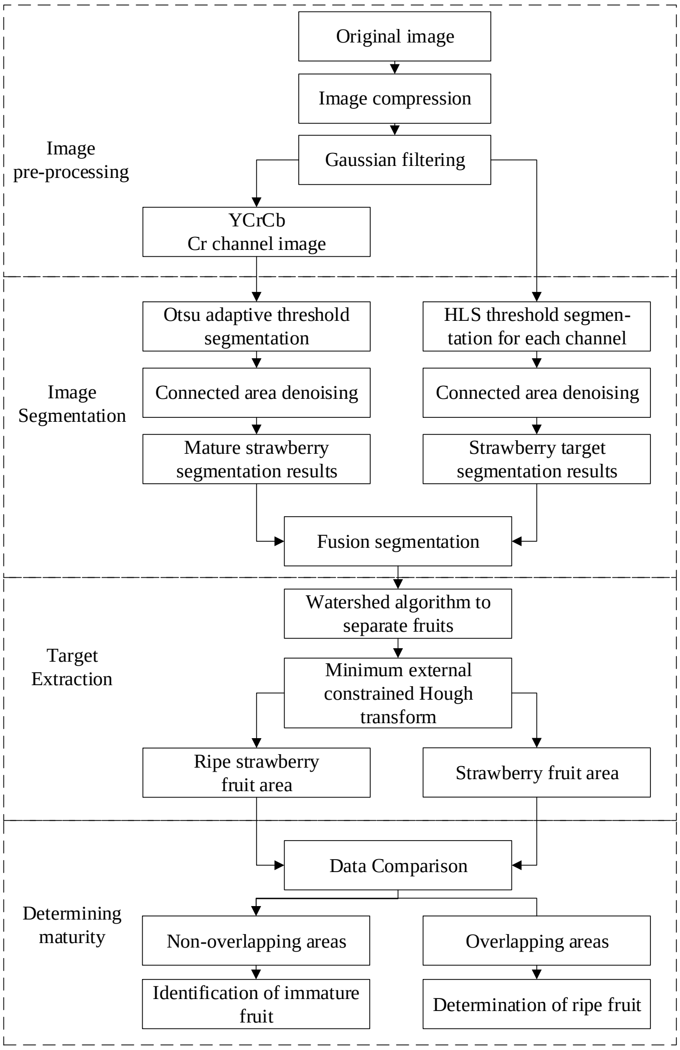

Fig 1: Strawberry identification and ripeness differentiation method

Ⅲ. FRUITS SEPARATED FROM THE BACKGROUND

This section discusses how to segment strawberries from their growing environment. Firstly, image pre-processing is needed, then strawberry image segmentation with different color models is performed, and then data fusion of segmented images with multiple color models is performed to achieve better segmentation results.

3.1 Strawberry Image Pre-processing

The images of elevated strawberry growth used in this experiment were collected from the strawberry plantation of Changchun Guoxin Modern Agri-culture Company. The original image size is 4624 pixels × 3468 pixels (4:3). In order to reduce the computational effort, the original image is compressed with a fixed size while preserving the image features, and the compressed image size is 800 pixels × 600 pixels, as shown in Fig 2(a).

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Firstly, the image is processed using Gaussian filtering to remove noise points. Secondly, single-channel images with different color models are used for image intensification to enhance the differences between strawberries and the environment for subsequent image segmentation.

The Lab color model is composed of a luminance channel (L) and two color channels, where the ‘a’ channel represents the change from red/magenta to green. Since the strawberry ripening process evolves from green to red, the a-channel image of strawberry is suitable for segmentation of ripe strawberries.

In the YCrCb color model, the Y channel represents the brightness of the image, the Cr channel represents the red component information, and the Cb channel represents the blue component information. Therefore, the Cr channel image of strawberry is also applicable to the segmentation of ripe strawberry. The a-channel image of strawberry and the Cr-channel image are shown in Fig 2(b) (c).

(a) (b) (c)

Fig 2: Image pre-processing (a) Compressed original image,(b) Lab-a channel images,(c) YCrCb channel images

3.2Adaptive Threshold Segmentation

After image preprocessing, the Ostu adaptive thresholding segmentation algorithm [18] was used to segment the a-channel and Cr-channel images of strawberries, respectively, and the segmentation results are shown in Fig 3. The Lab color model Ostuthresholding segmentation in Figure 3(a) is poor because the grayscale histogram of the a channel shows a bimodal distribution, resulting in the threshold nodes found by the Ostu adaptive thresholding segmentation algorithm are not suitable for segmenting ripe strawberries. Meanwhile, the grayscale histogram data distribution of the strawberry Cr channel is single-peaked, so it is able to find suitable thresholds.

It is inferred that the threshold segmentation of single color model is affected by factors such as illumination and background leading to segmentation failure, while the fusion threshold of multi-color model can well circumvent such problems and improve the stability of target recognition.

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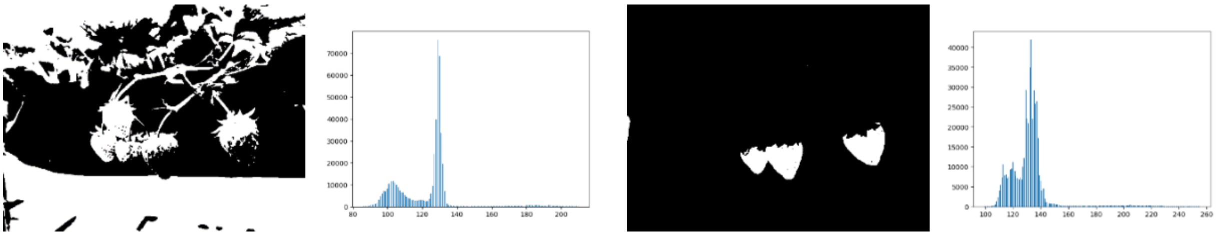

(a) (b) (c) (d)

Fig 3: Single threshold segmentation (a) Lab color model Ostu threshold segmentation, (b)Lab-achannel histogram, (c) YCrCb color model Ostu threshold segmentation, (d) YCrCb-Cr channel histogram

3.3Multi-color Model Threshold Segmentation

The single channel threshold segmentation based on the above two color models can only segment the ripe and semi-ripe strawberry images, but not the immature strawberries. The single channel threshold of the above two color models can only segment the ripe strawberry image, and the immature strawberry cannot be segmented because the color of the immature strawberry is similar to that of the strawberry stem and leaves. In order to segment the immature and mature strawberries from the surrounding part of the background, the HLS color model should be used to segment the strawberry fruit.

Segmentation was performed using the H, L, and S component thresh-olding of the HLS color model, and compared with the component thresholding segmentation of the Lab color model and the YCrCb color model. The strawberry images were processed using the color thresholding function cv2.inRange() function and the morphology change function cv2.morphologyEx() function in the OpenCV library.

Selected thresholding conditions for the HLS color model:

$0 \le H \le 32, 56 \le L \le 190, 100 \le S \le 255$.

Lab color model selected threshold conditions:

$60 \le L \le 255, 110 \le a \le 255, 160 \le b \le 225$.

Selected threshold conditions for the YCrCb color model:

$0 \le Y \le 255, 130 \le Cr \le 255, 40 \le Cb \le 105$.

The relationship between the input image, each component threshold, and the output image can be expressed by equation (1)(2)(3). *src* denotes the input image array, *lowerb* and *upperb* denote the lower and upper boundary arrays of each component of the image color model, respectively, and *dst* denotes the output array after thresholding.

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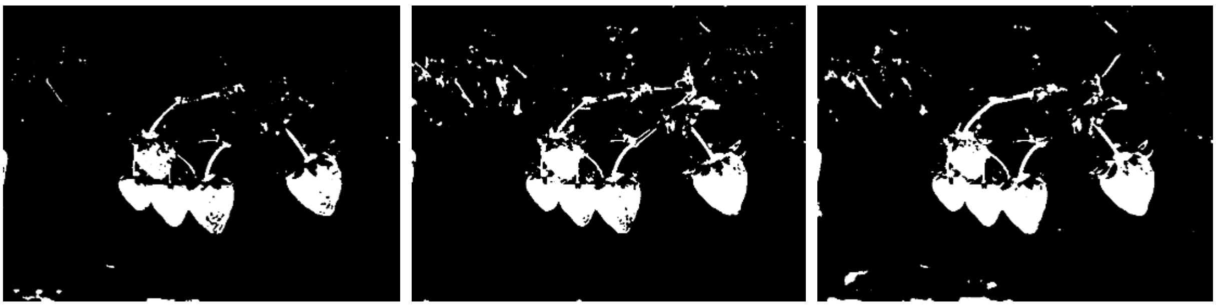
$$dst(I)_0 = lowerb(I)_0 \le src(I)_0 \le upperb(I)_0 \quad (1)$$

$$dst(I)_1 = lowerb(I)_1 \le src(I)_1 \le upperb(I)_1 \quad (2)$$

$$dst(I) = dst(I)_0 \wedge dst(I)_1 \quad (3)$$

When the value of a pixel point of the input image is outside the threshold range, the pixel point is set to 0 (black), while the pixel point within the threshold range is set to 255 (white), and the output image is a masked map with the same size as the input image.

The segmentation results shown in Fig 4(a)(b)(c) can be obtained by bitwise operation of the output image and the input image. Comparing the segmentation effects of the three color models of HLS, Lab and YCrCb for each component threshold, it was observed that the image segmented under the HLS color model had the least noise points and the smallest adherence area, and all the strawberry fruits in the image could be segmented.



(a) (b) (c)

Fig 4: Results of multi-color model threshold segmentation (a) HLS threshold segmentation,(b) Lab threshold segmentation, (c)YCrCb threshold segmentation

3.4Image Denoising

After the strawberry image is segmented by Ostu adaptive threshold, the ripe fruit can be effectively segmented. However, as can be seen from Fig 4(a), there are still some noise points in the strawberry binary image, and there are small white patches in the background. There are black spots inside. These disturbances mainly come from particles on strawberry stems, leaves and fruits.

The strawberry image can segment the ripe, semi-ripe and unripe strawberry fruits together by using the threshold of each component of the color model. However, according to the segmentation results in Fig 4(a)(b)(c), it can be seen that in addition to the strawberry fruit target, the segmented strawberry binary image also has strawberry stem and strawberry leaf patches, and the segmentation accuracy is poor. From the overall segmentation effect, HLS>Lab>YCrCb.

In order to achieve a better segmentation effect, the 8-neighborhood sequence method is used to process

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the binary image after strawberry segmentation, find adjacent connected regions and identify each connected region with different values [19]. According to the size of the pixel area of the same connected area, it is judged whether the connected area under the sign is a strawberry fruit (except the background), and the small area connected area outside the strawberry fruit is filled with black. Combined with the strawberry contour of the strawberry binary image, the interior of the strawberry fruit contour is filled with white, and most of the connected areas that are much smaller than the target area of the strawberry fruit are eliminated. As shown in Fig 5(b)(c)(d), most of the interference factors affecting strawberry fruit extraction have been eliminated, and the residual noise after the basic treatment can be clearly seen that the area segmentation effect of the HLS color space is the best, basically eliminating the strawberry Influence of stems and leaves.

(a) (b) (c) (d)

Fig 5: Single threshold segmentation (a) Single channel Ostu threshold segmentation, (b) Connection area denoising (HLS), (c) Connection area denoising (Lab), (d) Connection area denoising (YCrCb)

3.5Strawberry Separated from the Background

Advantage of single-channel Ostu threshold segmentation is that it can completely segment ripe strawberries. The strawberry binary image processed by threshold segmentation of connected area and filling of strawberry contour area has almost no interference. The threshold segmentation of each component in HLS color space can segment all strawberry images, but it is prone to interference information.

Fusion of the single-channel Ostu threshold segmentation results and the threshold segmentation results of each component is to perform bitwise OR operation on (a) and (b) (c) (d) in Fig 5 respectively, and use the single-channel low-noise binary image to reduce The interference of the binary image is divided by the threshold value of each component, and the effect is shown in Fig 6(b)(c)(d).

The strawberry can be separated from the environmental background by applying the bitwise sum operation of (a)(b)(c)(d) in Fig. 6 to the original image , respectively, as in Fig. 6 (e)(f)(g)(h).

The strawberry target can be extracted by performing a bitwise AND operation on the original image in (a)(b)(c)(d) in Fig 6, as shown in Fig 6(e)(f)(g)(h).

Ⅳ. STRAWBERRY FRUIT RECOGNITION AND MATURITY DISCRIMINATION

Strawberry fruit identification and ripeness judgment requires separating each strawberry individually, and here the fruits are separated one by one using the watershed algorithm. Then the Hough transform with improved minimum external constraint is used to locate the strawberry fruits, and finally the data of ripe

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strawberries and all strawberries are compared for ripeness discrimination.

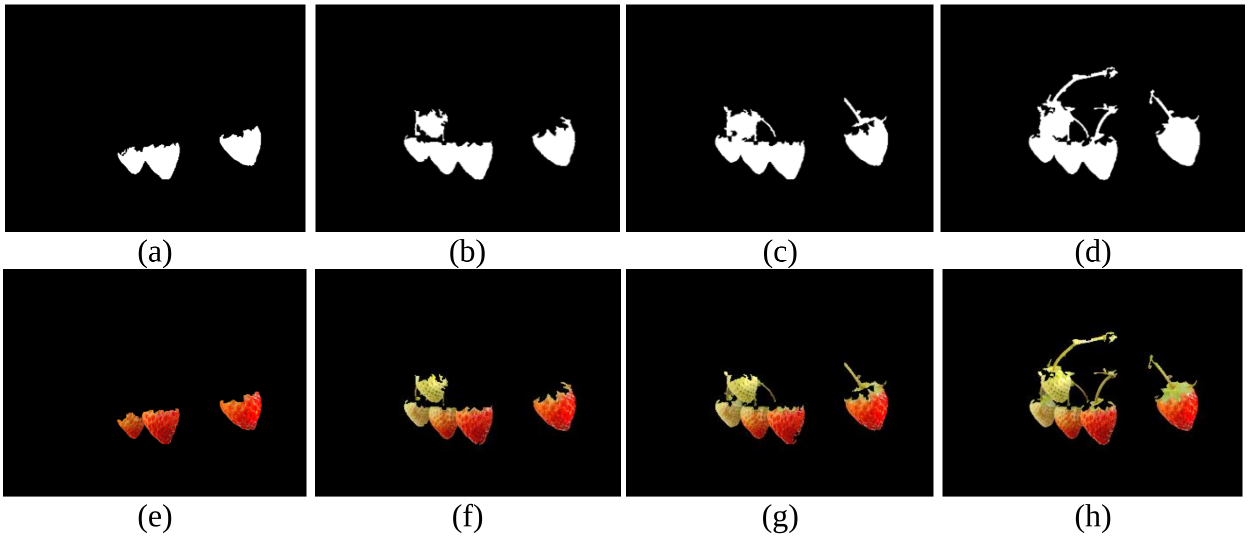

Fig 6: Results of the separation of the fruit from the background (a)Single channel segmentation, (b) HLS fusion segmentation, (c) Lab fusion segmentation,(d) YCrCb fusion segmentation, (e)Ripe strawberry extraction,(f)Strawberry extraction(HLS),(g)Strawberry extraction(Lab),(h)Strawberry extraction(YCrCb)

4.1Single Strawberry Separation

Watershed algorithm is a segmentation method based on image region[20], which can segment the sticky or covered strawberry fruit targets, so as to facilitate the next strawberry fruit target fitting work.

Watershed algorithm is used to segment the strawberry connected region. It is necessary to calculate the distance between each pixel of the fruit target in the strawberry binary image and the background point, that is, the distance between 0 points, as shown in Fig 7(a). Then find out each peak point as the water injection point in the watershed algorithm to determine the boundary between each strawberry fruit. As shown in Fig 7(b), the watershed algorithm divides each strawberry fruit.

4.2Strawberry Identification

Since the image of strawberry fruit is irregular, the main part can be fitted with a circle. The Hough transformation detects objects with specific shapes through a voting mechanism. Hough circle transformation is a three-dimensional Hough space. It extracts the edge contour information of the target image, draws a circle on the parameter plane with each non-zero point on the image, draws a circle with a set radius range, votes on the coordinate points covered by the circle, and finds the peak value on the parameter plane to get the corresponding center coordinates and radius[21].

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(a) (b)

Fig 7: Watershed algorithm to separate fruits(a) Distance conversion, (b) Watershed split

Due to the large gap between strawberry fruit and circle, it is easy to fit multiple circles during the actual Hough circle transformation of strawberry fruit, so it is impossible to locate accurately. Therefore, a strawberry target recognition method based on Hough circle transform with minimum circumscribed constraint is proposed. It can be seen that according to the circle transformation fitting equation, the center (x, y) and radius r of the fitting circle are two parameters that affect the result of the fitting circle.

Based on the minimum circumscribed constraint, Hough circle transformation adopts two constraints: the minimum circumscribed radius constraint and the contour center constraint.

Canny edge detection method is used to extract the edge information of strawberry image, and the contour information is drawn in the Fig 8(a). And draw the minimum circumscribed circle e of each contour, as shown in Fig 8(b). Obtain the center (x_o,y_o) and radius r_o of the circumscribed circle. If the maximum circumscribed radius is known, the radius constraint condition of Hough circle transformation is formula (4). r_{min} and r_{max} in the formula respectively represent the minimum radius and maximum radius of the detection circle, $S_i$represents the pixel area of the current contour, that is, the pixel area of strawberry fruit, $S_o$score represents the pixel area of the minimum circumscribed circle of the contour, and the product of the ratio of the area and the minimum circumscribed circle radius is set as the minimum radius of circle transformation. The maximum radius shall not be greater than the minimum circumscribed circle radius. The contour center constraint limits the fitting center to the segmented strawberry contour on the basis of the minimum circumscribed circle, as shown in Fig 6(a).

$$\begin{cases} r_{\min} = (S_i \div S_o) \times r_o \\ r_{\max} < r_o \end{cases} \quad (3)$$

4.3Strawberry Identification and Ripeness Determination

Strawberry fruit recognition is combined with single-pass threshold segmentation and HLS multi-channel threshold segmentation under Lab, YCrCb color model, followed by sexual watershed segmentation and minimum external constraint Hough circle transform localization recognition. The results of ripe strawberry fruit recognition based on single-pass threshold segmentation are shown in Fig 7(a), while the results of strawberry recognition based on fusion segmentation are shown in Fig 7(b). The strawberry fruits detected in each of these two images are arranged in order from left to right and from top to bottom for

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the subsequent image data comparison.

(a) (b)

Fig 8: Fruit profile with minimum outer circle (a) Strawberry outline, (b) Minimum external circle

Strawberry fruit ripening is usually divided into 4 stages, namely green ripening stage, white ripening stage, color change stage and red ripening stage, and for the convenience of strawberry fruit ripening discrimination the ripening stage is set into 2 cases, green ripening stage and white ripening stage strawberry fruit is considered as unripe strawberry, and color change stage and red ripening stage strawberry fruit is set as ripe strawberry. It is judged whether the coordinates of the center of the circle fitted to the strawberry fruit are within the fruit contour region, and if the coordinates of the ripe fruit and the appearance of the coordinates of all the fruit are in the same region, the region of the repeated strawberry fruit is judged as ripe strawberry, and the region of the non-repeated strawberry is judged as immature strawberry fruit.

By comparing the strawberry fruit regions in Fig 9(a) and (b), the immature strawberry fruits were screened as fruits No. 1 and No. 2 in Fig 9(b), and the mature strawberry fruits were fruits No. 3, No. 4 and No. 5 in Fig 9(b).

Finally, the identification results were labeled with the number 0 for immature strawberries and the number 1 for mature strawberries, as shown in Fig 9(c).

(a) (b) (c)

Fig 9: Results of maturity judgment (a) Results of ripe strawberry identification, (b) Results of all strawberry identification,(c)Results of strawberry ripeness determination

V.EXPERIMENTAL RESULTS

In order to verify the reliability of strawberry recognition and maturity discrimination method under multi-color model, 50 elevated strawberry images from different angles were randomly selected, and the methods of strawberry fruit recognition and maturity discrimination under multi-color model were used to

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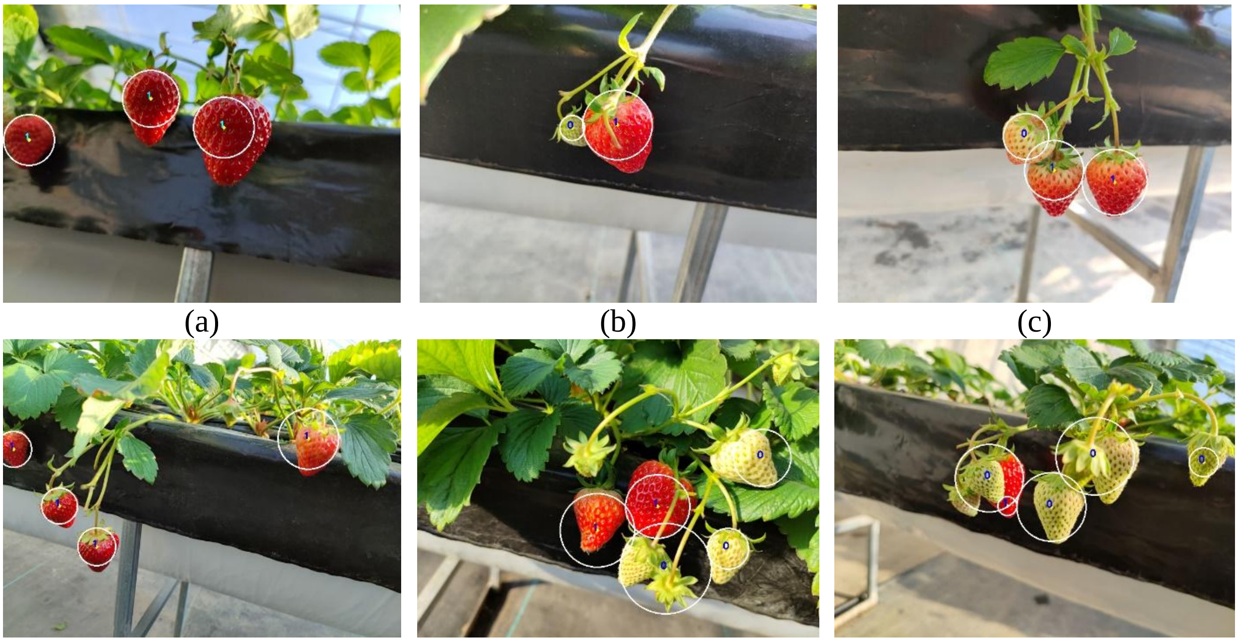
experiment the images. All strawberry images contain 173 strawberries, 83 immature strawberries and 90 mature strawberries.

Three groups of control experiments are shown in Figure 10. The first group of experiments studies strawberry images without occlusion, including three or less strawberries and multiple strawberries. In the second group of experiments, the strawberry fruit was covered by stems, leaves and fruit stalks, and in the third group of experiments, there were some overlapping strawberry fruits. Experiments were carried out to verify the accuracy of the method.

Table I shows the actual strawberry recognition effect of strawberry fruit recognition method based on multi-color model, When there is no shelter, the correct recognition rate of strawberry fruit is as high as 97.6%, However, in the case of occlusion and illumination, the recognition effect is poor, and the correct recognition rate of strawberry fruit is only 85.1%,Comprehensive consideration, the correct recognition rate can be stabilized at about 93.6%.



(a) (b) (c)

(d) (e) (f)

Fig 10. Results of strawberry fruit identification and ripeness determination (a) Three or less strawberries and uncovered, (b) Three or less strawberries and stems obscuring fruit, (c) Three or less strawberries and fruit shading fruit, (d) Multiple strawberries and uncovered, (e) Multiple strawberries and stems obscuring fruit, (f) Multiple strawberries and fruit shading fruit

TABLE I. Strawberry fruit identification

STRAWBERRY IDENTIFICATION	STRAWBERRY TOTAL (PCS)	SUCCESSFULRE COGNITION (PCS)	CORRECTRECO GNITIONRATE (%)

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NO OBSTRICTION	125	122	97.60
OBSCURED	47	40	85.10
TOTAL	173	162	93.60

Table II shows the experimental results of strawberry fruit maturity judgment method based on multi-color model.

According to the number of strawberry fruit images in a single image, it is found that the more dense the strawberry fruit, the lower the accuracy of maturity discrimination.

TABLEII. Judgment of strawberry fruit ripeness

NUMBER OF FRUITS	RIPE STRAWBERRY (PCS)	ACCURACY RATE (%)	UNRIPE STRAWBERRY (PCS)	ACCURACY RATE (%)
THREE OF LESS STRAWBERRY	26	100.00	25	92.00
MULTIPLE STRAWBERRY	73	97.30	49	83.70
Total	99	98.65	74	87.85

The color characteristics of mature strawberry fruit are more significant, the judgment accuracy is about 98.65%, and the recognition is more accurate; Because the color characteristics of immature strawberry fruits are similar to those of strawberry stems and leaves, so the accuracy of judging immature fruits is low, only about 87.85%.Overall, on the basis of successful recognition, the judgment accuracy of strawberry fruit is about 93.25%.

Ⅵ. CONCLUSION

The method of strawberry recognition and maturity judgment under multi-color model is greatly affected by light exposure. In the experiment in non strong light and non dark natural environment, the test effect is good. The accuracy of overhead strawberry recognition is 93.6%, and the accuracy of strawberry maturity is 93.25%; However, in special environments such as direct light and dark environment, the recognition and judgment accuracy of this method is reduced.

This method based on the color features of the image is not only applied to the recognition of strawberry fruit, but also applicable to any other object recognition with similar color and shape features, such as tomato, apple and so on.

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REFERENCES

[1]XieZhiyong,Zhang Tiezhong,Zhao Jinying. Ripened Strawberry Recognition Based on Hough Transform. Transactions of the Chinese Society for Agricultural Machinery,2007(03): pp. 106-109.
[2]Yan Yong, Chen Lifu, GuoKunkun, Jiang Zhaohui, Rao Yuan. Mature strawberry recognition based on gradient Hough circle transformation under lab color model. Journal of Anhui Agricultural University, 2020,47 (03): pp. 488-493.
[3]Eaton G., Busch A., Bartels R.,Gao Y.Colour Analysis of Strawberries on a Real Time Production Line. 2018 Digital Image Computing: Techniques and Applications (DICTA), 2018, pp. 1-7.
[4]Yan Jianwei, Zhao Yuan, Su Xiaodong, Liu Hongyun, Zhang Lewei, Zhang Fugui, Fan Weiguo, He Lin. Rosa Roxbunghii Fruits Recognition Based on Deep Learning in Natural Environment. Journal of Agricultural,2020,42(11):pp.23-28.
[5]Liu Lijuan, Dou Peipei, Wang Hui. Image recognition algorithm research of overlapped apple fruits in the natural environment. Journal of Chinese Agricultural Mechanization, 2021,42(06): pp. 174-181.
[6]Wu Pinghui, Chen Xin, Zhang Xin, DuanDandan, Tang Bingxia, Zhang Yunhe. Segmentation and recognition method of facility tomato based on clustering improved gray wolf algorithm. Modern manufacturing engineering, 2021(06): 83-89.
[7]Zhao Ling, Zhou Guihong. Study on recognition technology of strawberry maturity based on color feature. Journal of Hebei Agricultural Universit, 2017,40(02): pp. 97-101.
[8] AnraeniS., IndraD., AdirahmadiD., PomalingoS., Sugiarti,MansyurS. H.Strawberry Ripeness Identification Using Feature Extraction of RGB and K-Nearest Neighbor. 2021 3rd East Indonesia Conference on Computer and Information Technology (EIConCIT), 2021, pp. 395-398.
[9]Liu Xiaogang, Fan Cheng, Li Jianian, GaoYanli, Zhang Yuyang, Yang Qiliang. Identification Method of Strawberry Based on Convolutional Neural Network. Transactions of the Chinese Society for Agricultural Machinery, 2020, 51(02): pp. 237-244.
[10] Fan Y., Zhang S., Feng K., Qian K., Wang Y., Qin S. Strawberry Maturity Recognition Algorithm Combining Dark Channel Enhancement and YOLOv5.Sensors 2022, 22, 419.
[11]Zhao Shida. Research on Strawberry recognition technology based on machine vision. Wuhan University of light industry, 2018.
[12]Li Xin. Research on identification and classification method of elevated strawberry for machine picking. Southeast University, 2018.
[13]IlyasT., Khan A., UmraizM., JeongY., H. Kim. Multi-Scale Context Aggregation for Strawberry Fruit Recognition and Disease Phenotyping.in IEEE Access, 2021, 9: pp. 124491-124504.
[14] Wang Xiaohui, Zhou Kunpeng. Research on recognition methods for red tomato image in the natural environment. Journal of Zhejiang University(Agriculture and Life Sciences), 2021, 47(03): pp. 395-403.
[15]Wang Wenjie, Gong Liang, Wang Tao, Yang Zhiyu, Zhang Wei, Liu Chengliang. Tomato Fruit Recognition Based on Multi-source Fusion Image Segmentation Algorithm in Open Environment. Transactions of the Chinese Society for Agricultural Machinery, 2021,52(09): pp. 156-164.

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[16]Yang Yu, Kailiang Zhang, Li Yang, Dongxing Zhang. Fruit detection for strawberry harvesting robot in non-structural environment based on Mask-RCNN,Computers and Electronics in Agriculture,2019,163:104846.
[17]Venkatesh N.Y, HegdeS.U.Fine-tuned MobileNet Classifier for Classification of Strawberry and Cherry Fruit Types. 2021 International Conference on Computer Communication and Informatics (ICCCI), 2021, pp. 1-8.
[18]Li X., Li J.,Tang J.A deep learning method for recognizing elevated mature strawberries. 2018 33rd Youth Academic Annual Conference of Chinese Association of Automation (YAC), 2018, pp. 1072-1077.
[19]Miao Longyuan, Yu Zhenglin. Regional Filling Algorithm Based on Connected Region Labeling. Journal of Changchun University of technology, 2018,41(4): pp. 115-117.
[20]Li Wenyong, Chen Meixiang, Xu shupo, et. Diameter measurement method for immature apple based on watershed and convex hull theory. Transactions of the Chinese Society of Agricultural Engineering, 2014,30 (23): pp. 207-214.
[21]Li Han, Tao Hanxuan, Cui Lihao, Liu Dawei, sun Jiantong, Zhang Man. Recognition and Localization Method of Tomato Based on SOM-K-means Algorithm. Transactions of the Chinese Society for Agricultural Machinery, 2021,52(01): pp. 23-29.