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Application of Image Recognition in Citrus Fruit Classification

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Abstract

The application technology of image recognition technology in the classification of citrus fruits directly and effectively solves the problem of the efficiency of picking citrus through the application of graphic grading. Other solutions for graphic grading cannot effectively solve the problem of picking and sorting. The application of image recognition in the classification of citrus fruits successfully solved the citrus picking and grading, and the information collected by image recognition was used to achieve the multi-objective grading of citrus, which also provided support for subsequent design.

Keywords: *Picking Robot, Multi-Objective, Fruit Grading, Citrus Fruit, Image Processing;*

1. Introduction

Human eyes recognize images by shape, and intelligent image recognition will find a specific form from the recognized image, and then use this regular form to make corresponding judgments [1-2]. The image recognition architecture is developed based on the human visual system. The layers of the network are connected together to extract abstract features from the picture. The image recognition system obtains the correct answer through a series of connections, but even if there is only a slight difference, the system will reply that the answer is wrong. When the difference is enlarged, the recognition system cannot define the standard [3-4].

The citrus fruit grading process of the image recognition algorithm divides the image into small pieces, and makes a decision for each small piece, for example, this piece contains insects, and which piece contains non-smooth pee l[5-6]. Next, the image recognition algorithm gathers every small decision made to determine what kind of problem a fruit has, and it has reached the classification of the fruit. The result proves that the accuracy of the system is very high when recognizing objects.

2. Citrus image acquisition

The citrus picking environment under natural conditions mainly grows in a trellis style. The background of citrus picking environment includes leaves, tree trunks, sky, weeds, etc. In order to remove the influence of weeds and other backgrounds, this study used the method of acquiring images from the bottom of citrus to classify multi-target citrus fruits.

The image acquisition device is shown in Figure 1 (d represents the shooting distance), which includes the machine vision part, auxiliary light supplement device and computer. The machine vision part adopts Microsoft camera to obtain images. According to weather conditions, working time (day or night), and lighting conditions, you can choose whether to use auxiliary light supplement device. The images collected by machine vision are transmitted to the computer through the data connection line.

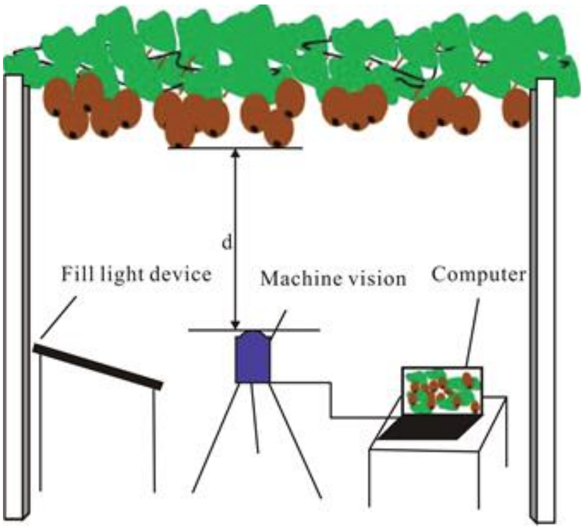

Figure 1. Citrus image acquisition device.

The selected distance is 60cm from the camera to the bottom of the fruit. The collected image format is jpg format, and the image size is 640×360 pixels. Among them, the citrus fruit is the part marked by the circle. It can be seen that for the positioning of the fruit, it is extremely convenient to be able to classify the fruit part for the subsequent positioning process.

3. Fruit grading method

3.1. RGB image processing method

Using image Pro plus software, draw a cross-section line on different positions of the citrus image. The horizontal section line is selected as: fruit on the section line; no fruit on the section line. As shown in Figure 2, it can be seen from the figure that the RGB component of the citrus fruit part has a relationship that the R component is greater than the G component, and the G component is greater than the B component. On the background (except for citrus fruits), the R component and G The phase difference between components or B components does not fluctuate much.

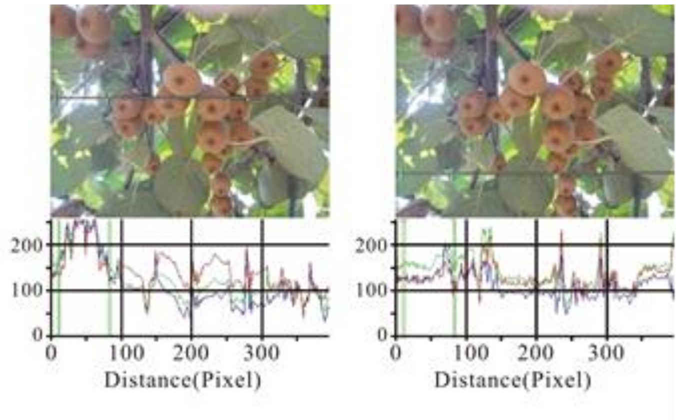

Figure 2. RGB component profile analysis.

Therefore, the R-G method is used to relatively strengthen the red component of citrus, highlight the citrus part, and weaken the influence of noise such as leaves and trunks. Subsequent threshold segmentation is used to eliminate small area noise to obtain the citrus part.Through edge detection, the corresponding edge of the citrus is obtained, so as to retain the part surrounded by the edge and remove the part outside the surround, which is to achieve the segmentation of the fruit to obtain the fruit part, and finally Perform threshold segmentation to get the classification of the fruit part.

3.2. Image processing process

The specific process is as follows:

(1) Read the image

Case images can be selected arbitrarily;

(2) Obtain the RGB component image and grayscale image of the image

(3) Perform R-G component processing on the image

In the analysis of image processing methods, the citrus fruit part of the image is well highlighted after R-G component processing. (4) Global threshold segmentation of R-G component images

For the global threshold segmentation of the image, the formula is as follows

$$g(x,y)=\begin{cases}1, f(x,y)>T\\0, f(x,y)\le T\end{cases} \tag{1}$$

Among them, f(x,y) is the pixel value of point (x,y), g(x,y) is the segmented image, and T is the global threshold.

Perform global threshold segmentation on the obtained RG component image. For a multi-target citrus image, the pixel value of the gray image obtained after the RG component is divided into: fruit part: f(x, y) ∈ (20, 70); The background is: f(x,y)∈(20,70), therefore, the global threshold is set to T=18.

(5) Remove small area noise

The segmented image is processed to remove small areas, which are generally part of the background of tree trunks and leaves. The area of this part of the noise is several times smaller than the area of a single fruit noise, or even more than ten times, which are all small area noises. A fruit = nA small area noise, A represents pixel area, n represents multiple, A small area noise ∈(5,220), the threshold of small area noise taken in this paper is 230.

(6) Prewitt edge detection

The edge detection is performed on the obtained image after removing the small area by the prewitt operator, and the range surrounded by the edge is the range of the multi-target citrus fruit.

(7) Multi-target citrus fruit extraction

The image after removing the small area area and the gray image of the original image are multiplied, and the operation expression is

$$C(x,y)=A(x,y)*B(x,y) \tag{2}$$

Among them, A(x,y) and B(x,y) represent the grayscale image of the original image and the image after removing the small area noise, C(x,y) represents A(x,y) and B(x, y) The result after the operation.

Thus, after prewitt edge detection, the image of the fruit part surrounded by the edge is extracted. The image processing result of the case is shown in Figure 6(e).

(8) Fruit extraction

For the grayscale image of the fruit part, the extraction of the fruit part only needs to perform the global threshold segmentation to extract the fruit, because the fruit part and the fruit part are different in the pixel value of the gray image: the fruit part is: h(x, y)∈(120, 180); the background is: h(x, y) ∈ (40, 100), so the same as (4) for the global threshold segmentation of the obtained fruit parts, at this time T=100. Of course, this segmentation method still has some errors, but for multi-target citrus picking robots, the error is within the tolerance range (subsequent analysis).

4. Multi-target fruit classification verification experiment

4.1. Experimental setup

The machine vision part uses a Microsoft camera (LifeCam Studio CMOS, which uses CMOS as a photosensitive element, a dynamic resolution of 2304×1728, and a maximum frame rate of 30FPS) as the main component, and uses autofocus to obtain images. The image format is selected as jpg format. , The resolution is 640×360 pixels, and it is passed to the computer through the USB2.0 interface. The computer uses a Lenovo ThinkPadT400 laptop (2GB of memory, 2.53GHz frequency). According to the weather conditions, the auxiliary light supplement device can be selected to obtain the image supplement light, and the auxiliary light supplement device is provided with a stepless dimmable LED film and television flat light (CM-LED1200HS, Wuhan Kema Film and Television Lighting Technology Co., Ltd., the maximum illuminance is 1m away 1200lux).

4.2. Experimental method

This experiment uses the method we proposed above, and uses fruits and fruits as the test items in this experiment. The color difference method is used to obtain the range of multi-target citrus fruit and remove the background noise, and then use threshold segmentation to obtain the characteristic part of the multi-target citrus fruit; three indicators of false positive rate, false negative rate, and overlap coefficient are used to evaluate the classification of fruits and fruits . The false positive rate refers to the ratio of the background being mistakenly divided into the target, the false negative rate refers to the ratio of the target being mistakenly divided into the background, and the overlap coefficient refers to the ratio of the overlapped target with the real target.

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Here, the false positive rate is the ratio of the fruit being mistakenly divided into the background, the false negative rate is the ratio of the background being mistakenly divided into the fruit, and the overlap coefficient refers to the ratio of the number of divided targets to the actual target. In the fruit overlap rate, if the area of the fruit after division is more than half, the fruit is considered to be completely divided, and if it is less than half, the fruit is not divided. Finally, the error analysis of the obtained results is performed, and the average value of the overlap coefficient (including fruit or fruit) of the grading images is taken as the true value of the grading, then the grading error of each image can be expressed as

$$\sigma_i = \left| X_i - \frac{1}{n}\sum_{i=1}^{n} X_i \right| \tag{3}$$

Among them, Xi represents the fruit overlap coefficient of the i-th image or the fruit overlap coefficient of the i-th image.

5. Experimental results and data analysis

5.1. Results

According to the citrus fruit shape and color characteristic value computer query information dictionary, the fruit shape and color are individually graded and the sugar acidity is non-destructively tested. If the characteristic value exceeds the shape and color retrieval range, which grade interval is the shortest distance to which grade interval is rated as the shortest The distance principle implements the level definition; the color feature value across 2 levels is based on which level the index belongs to which level is the principle. If there is a situation where the index numbers of the two levels are the same, the lower level of the 2 levels is used. assessment. Comparing the results of manual grading, the correct rate of computer shape grading is 100%, and the correct rate of color grading is 98%. The relative error ranges of sugar content and acidity nondestructive testing of 500 test samples of 5 colors are -19.79%~30.90% and -19.37%~ 24.38%.

According to the complexity measure C(Y) and Shannon information entropy H(Y), the two characteristic identification parameter values are searched by computer for the retrieval table of Bingtang orange fruit diseases and insect pests. The physiological boron deficiency, rust tick, and oil cell dent disease are three kinds of diseases and insects as pest defects. The correct recognition rates of 100 test samples of each fruit were 93%, 95% and 92%, respectively, and the average correct recognition rate of 3 kinds of pests and diseases was 93.33%.

5.2. Analysis

(1) Shape classification analysis

According to the steps of the shape classification test method, calculate the fractal dimensions of the two projection surfaces of the stalk surface and the side surface of the healthy fruit perpendicular to each other, D1 ∈ [1.0102,1.0170], D2 ∈ [1.0189,1.0258], standard deviation s1=0.0009, s2= 0.0013. The projection of the stalk surface of citrus fruit is close to a circle, and the fractal dimension is small, and the projection of the side of the fruit is close to an ellipse, and the fractal dimension is large. According to the perimeter-area fractal dimension shape grade interval, the four grades of excellent, first-class, second-class and other grades are clearly defined. Figure 3 shows the calculated shape grading of 100 test samples, ①, ②, ③, ④, ⑤ and Ⅰ, Ⅱ, Ⅲ, Ⅳ, and Ⅴ are the boundary points inf and sub of the stalk surface and the shape grade interval with the side, respectively. The superior grades are the rectangular area enclosed by the horizontal line and the vertical line Ⅰ and Ⅱ. The second-class and outer-class are respectively ②, ③ horizontal line and vertical line Ⅱ, Ⅲ, ③, ④ horizontal line and vertical line Ⅲ, Ⅳ, ④, ⑤ horizontal line and vertical line Ⅳ, Ⅴ "7"-shaped area enclosed In the picture, there are 7 excellent fruits, 18 first-class fruits, 39 second-class fruits, and 36 second-class fruits.

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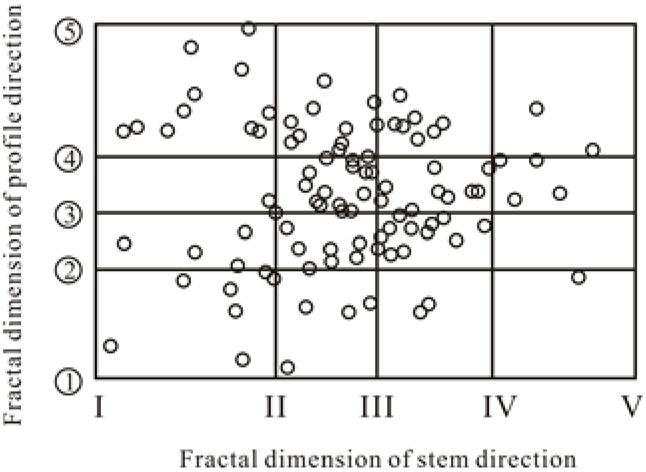

Figure 3. Fractal dimension distribution of test samples.

(2) Color grading analysis

The color characterization of citrus fruit analyzes the multifractal characteristics of the fruit according to the steps of its test method. As shown in Figure 1, the partition function is approximately radial in the range of δ =26-29. This scale interval can be considered as scale-invariant. There is a theoretical basis for studying the characteristics of its multifractal spectrum.

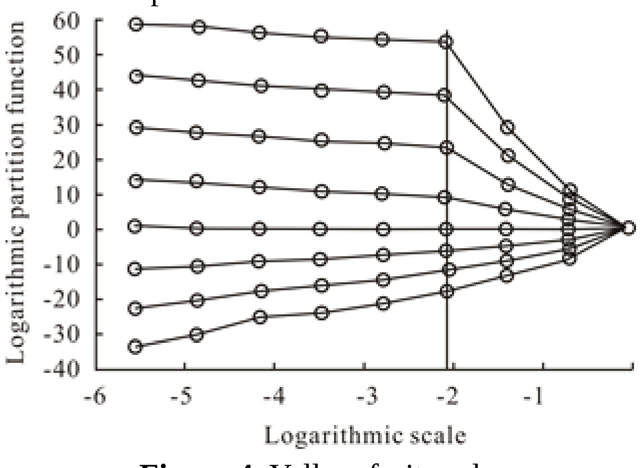

Figure 4. Yellow fruit scale.

It can be seen from Figure 4 that although the shape of the fractal spectrum is different, there are also obvious differences in the position. The height and width of the fractal spectrum are respectively coordinated with the centroid vertical and horizontal coordinates. On the one hand, it reduces the dimension of the color characterization data. Avoid data cross and overlap, fully reflect and express the difference in citrus fruit color between grades. Figure 4 Unit coordinated multifractal spectrum height and width distribution. Citrus fruits are color-graded by coordinated multifractal spectrum height and width in 4 hue interval units and 8 color feature parameters, which are more accurate than the color grading parameter with the fractal dimension of 5 equal hue regions from 0° -100° . Compared with the color description of fruit color grading based on the average value of red, green or blue, the grading accuracy is significantly improved.

(3) Non-destructive testing and analysis of sugar acidity

According to the partial least squares non-destructive testing model of sugar acidity, the multifractal spectrum height and width are mapped with the unit coordinate of 30° -50° , 50° -70° , 70° -90° and 90° -120° The predicted standard deviations of sugar content and acidity, sugar content and effective acidity of citrus fruits are 0.7652 and 0.3587, respectively, and the correlation coefficient r between the sugar content and acidity non-destructive test value and actual value of 500 test samples in 5 colors is above 0.8 and 0.7, respectively. Five kinds of colors are indicated. The degree of correlation between non-destructive testing and physical and chemical testing of sugar and acidity of 20 test samples in each color. The 8 color characteristic parameters of unit coordinated multifractal spectrum height and width are used for non-destructive detection of sugar content and acidity of citrus fruits. The relative error is lower than that of the fractal dimension of 0° -120° 6 equally divided hue area. The sugar content and acidity are not destructive. The correlation coefficient between the detected value and the actual value is high.

Inspect the pixels between 0° -50° , the pests and diseases in this area account for more than 95% of the pixels of 0° -360° . The pixel distribution in this hue interval does not lose generality, and it also reduces the calculation work. Table 3 shows the probability range of pixel distribution and the complexity measure C(Y), Shannon information entropy H(Y) average value of the 0° -50° hue interval of the detected sample. It can be seen that

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the fruit surface of different diseases and insect pests The two parameters C(Y) and H(Y) are different for harmful defects.

From Table 1 fruit grading evaluation indicators, it can be seen that the false positive rate is greater than 10%, NO.1, NO.4, NO.16, and NO.17; the false negative rate greater than 10% is NO.2, NO.3 , NO.5, NO.9, NO.19, NO.20. Through analysis, it is found that in the images of NO.1, NO.4, NO.16, and NO.17, some leaves are yellow due to sunlight exposure, and their color is similar to the color of the fruit, which causes the background of the leaves to be mistakenly classified as fruit targets, so The false positive rate in these images is too large; in the NO.2, NO.3, NO.5, NO.9, NO.19, and NO.20 images, because individual fruits are immature, their color is shown as Green, which causes it to be similar to the leaf background color, and the fruit target is mistakenly classified as the leaf background, so the false negative rate is higher in these images.

Table 1. Fruit classification evaluation index.

NO.	The number of fruit	False positive rate/%	False negative rate/%	overlap index/%
1	5	20.00	0.00	83.33
2	7	2.32	18.60	81.40
3	8	7.89	13.16	86.84
4	11	18.18	0.00	100.00
5	11	5.56	11.11	97.44
6	14	5.88	0.00	94.12
7	15	0.00	0.00	90.91
8	23	7.27	9.09	89.09
9	27	0.00	16.67	83.33
10	33	0.00	10.00	80.00
11	33	7.69	7.69	84.62
12	35	7.41	7.41	92.60
13	36	7.69	7.69	92.31
14	39	7.41	0.00	92.60
15	41	7.14	7.14	96.43
16	43	11.63	4.65	95.35
17	44	16.32	2.04	97.95
18	47	0.00	9.25	88.89
19	49	0.00	17.78	82.22
20	54	3.13	15.63	84.37
Mean	28	6.78	7.90	89.69

Table 2. Fruit classification evaluation index.

NO.	The number of fruit	False positive rate/%	False negative rate/%	overlap index/%
1	5	20.00	0.00	83.33
2	7	2.32	20.93	81.40
3	8	2.63	15.79	86.84
4	11	9.09	4.54	100.00
5	11	0.00	5.56	94.44

6	14	0.00	5.88	94.12
7	15	9.09	9.09	90.91
8	23	1.81	12.73	85.45
9	27	16.67	0.00	83.33
10	33	10.00	10.00	80.00
11	33	0.00	7.69	92.31
12	35	3.70	3.70	88.89
13	36	3.85	3.85	92.31
14	39	11.11	3.70	85.19
15	41	7.14	0.00	96.43
16	43	11.63	4.65	95.35
17	44	4.08	7.55	90.57
18	47	1.85	12.96	85.19
19	49	2.22	11.11	86.69
20	54	3.13	12.50	84.37
Mean	28	6.02	7.61	88.86

From Table 2 fruit grading evaluation indicators, it can be seen that the false positive rate is greater than 10%, NO.1, NO.9, NO.14, and NO.16; the false negative rate greater than 10% is NO.2, NO.3 , NO.8, NO.18, NO.19, NO.20. Through analysis, it is found that in the images of NO.1, NO.9, NO.14, and NO.16, because part of the leaves are divided into fruits in the segmentation of the fruit, and the color characteristics of the upper part of the leaves are similar to the color characteristics of the fruit, and a small part The trunk is wrongly divided into fruits, causing the background to be wrongly divided into targets, so the false positive rate is too large in these images; in NO.2, NO.3, NO.8, NO.18, NO.19, In the NO.20 image, due to the fruit segmentation, the immature individual fruits show that the fruit color characteristics are similar to the background leaf color characteristics, and the fruits are mistakenly divided into the background, which causes the fruit targets of these fruits to be mistakenly divided into the background in the fruit segmentation. , And during the threshold segmentation process, the fruit is incorrectly classified into the background, so the false negative rate is too large in these images.

Combining the evaluation indexes of fruit grading in Table 1 and the evaluation indexes of fruit grading in Table 2, it can be seen that the average false positive rate and the average false negative rate are below 10%, and the average overlap coefficient is above 88%.

In order to more effectively analyze the grading of citrus multi-objective fruits, the error σ i proposed in the experimental method is introduced, and the grading error of 20 images is drawn.

It can be seen from the fruit grading error that the grading error in the images of NO.4, NO.10, and NO.15 is relatively large.Through analysis, the reasons for the error are: some fruits in the image are blocked by leaves, trunks, and some are not. The color component of the ripe fruit shows that the green component is the main part, which is caused by the color similar to the background.

(1) The RGB component value of the fruit part of the citrus image has a relationship that the R component is greater than the G component and the B component. On the background, that is, the difference between the R component and the G component or the B component except for the citrus fruit. Not big.

(2) A citrus fruit multi-object grading method is proposed. The fruit is used as the grading feature point. First, the separation of the fruit target and the background is achieved, and finally the fruit feature points are classified according to the fruit target. The

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accuracy rate of this algorithm is 88.86%; The average false positive rate and the average false negative rate are both below 10%. When the number of fruits is between 41 and 45 (NO.15~NO.17 in the table), the grading rate is above 90%.

(3) The error analysis of the grading results of each group of images in the experiment is carried out. The reason for the large error is that the fruits are obscured by leaves, trunks, etc., and some of the fruits are immature, which causes the fruits to be obscured and wrong in the image grading process. Divided into background and other circumstances.

6. Conclusions

This paper proposes a multi-target fruit grading method based on citrus fruit images, from the previous single fruit grading to multi-target fruit grading, and the fruit part is graded to meet the operational requirements of multi-manipulator citrus picking robots, and the information obtained reaches the multi-target grading Purpose, to provide information support for the subsequent path planning of the robotic arm and the end effector design. This method can also provide a reference for the classification of other fruits such as apples and citrus. Although this paper proposes a multi-objective fruit grading method for citrus, and meets the error-tolerant rate requirements of the end effector picking fruits, the accuracy of the algorithm needs to be further improved or new algorithms are needed; due to the large number of fruits for multi-objective classification , The management of the subsequent coordinate point data and the distribution of the picking sequence need to be further studied.

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