

Retraction

Retracted: Target Recognition and Trajectory Planning of Apple Harvesting Robot considering Color Multimedia Image Segmentation Algorithm

Advances in Multimedia

Received 15 August 2023; Accepted 15 August 2023; Published 16 August 2023

Copyright © 2023 Advances in Multimedia. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their

agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Wang, "Target Recognition and Trajectory Planning of Apple Harvesting Robot considering Color Multimedia Image Segmentation Algorithm," *Advances in Multimedia*, vol. 2021, Article ID 2817869, 8 pages, 2021.

Research Article

Target Recognition and Trajectory Planning of Apple Harvesting Robot considering Color Multimedia Image Segmentation Algorithm

Ya Wang 

Puyang Vocational and Technical College, Puyang 457000, Henan, China

Correspondence should be addressed to Ya Wang; 20130823@stu.nun.edu.cn

Received 21 July 2021; Accepted 25 August 2021; Published 16 September 2021

Academic Editor: Zhendong Mu

Copyright © 2021 Ya Wang. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

For the purpose of significantly reducing the processing time of the apple harvesting robot during the harvesting process, it is highly necessary to carry out the corresponding studies on the methods for rapid recognition and trajectory planning. Through the comprehensive application of information relevance, the image processing area can be reduced. For image recognition and trajectory planning, the related template matching algorithm for removing the mean value and normalization product can be adopted, and segmentation methods based on different threshold values can be used for the realization of the effect. Subsequently, the comparative experiments are properly carried out to verify the effectiveness of the method used.

1. Introduction

The apple harvesting robot is the product of the continuous advancement of science and technology. It is a high-tech confrontation platform that stands for a kind of human wisdom and also a contest of comprehensive technology between two parties [1, 2]. The robot can make judgment on the highly complex trends in the field based on the corresponding rules so as to guide itself to make the optimal decision and then take the corresponding actions that are conducive to defeating the opponent [3]. During the contest between the two parties, the apple harvesting robot focuses closely on the vision system to carry out a comprehensive search for the related environmental information such as goals and balls. Subsequently, the laser, infrared, and other related ranging systems are used to conduct global positioning of the robot and comprehensive detection of the obstacles and then integrate the information obtained based on certain rules to form certain action instructions and demonstrate the operations accordingly [4, 5]. Hence, the requirements for real-time performance, robustness, and accuracy are very high. When the robot gradually approaches the center of the image in the center of the target

fruit, it usually needs to recognize the image multiple times and implement the trajectory planning multiple times before it can accomplish the task [6]. In the past, the process of acquiring each image was actually carried out by executing a certain recognition algorithm repeatedly. The recognition time spent was usually close to almost the same. The final overall recognition time was actually the sum of the recognition time for all images [7]. In the whole harvesting process, the recognition time is an integral part. If the recognition time can be reduced, the harvesting speed of the robot can be significantly increased, and the gap between manual harvesting and machine harvesting can be further narrowed so as to improve its practical value tremendously. Therefore, in the study of this paper, the author has conducted a comprehensive application of the information relevance of the images to investigate the rapid recognition method and the corresponding trajectory planning method.

2. Rapid Recognition and Trajectory Planning Method

2.1. Image Segmentation. The reason for selecting the image segmentation method based on color features is that there is

a particularly evident color difference in the apple fruit and the background. A set of pictures of an orchard is taken in a natural environment, focusing closely on the background and apple fruit area. The background mainly refers to the branches, the sky, the green leaves, and other areas where the apple fruit is located. The values of the color factors R, G, and B are subject to comprehensive statistical and other related analyses. After statistical analysis, we can see that, regardless of the color difference R- or 2R-G-B, the apple fruit can be distinguished effectively from the background color based on its own method [8]. In normal circumstances, the R-G calculation method is not only relatively convenient, but also extremely simple. Hence, the color difference R-G is used as the color feature value in the image segmentation process of this paper. The color difference curve corresponding to R-G is shown in Figure 1.

As shown in Figure 1, we can determine the fixed threshold value and then use the value obtained to identify the corresponding fixed threshold on the fruit image. However, it is found through a large number of experiments that the segmentation method based on the fixed threshold value still has some defects. The main reason is that it is not particularly adaptable to the changes in light. On this basis, the author has applied the OTSU method, which is often referred to as the segmentation method based on the dynamic threshold value. As a dynamic threshold segmentation method, it has excellent performance. In the process of acquiring the dynamic threshold value, it is necessary to perform calculation on three aspects based on this method. The first aspect is the target class in the image, the second aspect is the background class with the minimum variance, and the third aspect is the background class with the maximum variance.

After the image segmentation is completed, there are still some relatively isolated small holes, tiny dots, and minor burrs. However, these noises can have a serious influence on the recognition. Thus, we need to take the relevant measures to eliminate the influence of the noise [9]. In this paper, we have applied the ‘‘Corrosion-remove-expansion’’ method effectively. First of all, the corresponding corrosion calculation is carried out, and then the image after segmentation is calculated based on a certain method. The purpose is to eliminate the target boundary point so that it can present a phenomenon of gradual inward shrinkage. Subsequently, the small area removal operation is fully applied, the purpose of which is to eliminate some remaining small areas based on the corresponding method. Finally, the expansion calculation is carried out comprehensively, the purpose of which is to expand some of the points of contact and then merge them into the target. Through the processing described above, we can segment the image into two parts: the first part is the background, and the second part is the fruit.

2.2. Identification of the Target Fruit. In the process of harvesting fruits, if a single-manipulator harvesting robot is used, it can only carry out the task in a manner of harvesting the fruits one by one. If there are multiple fruits in the image, then it is necessary to identify the target fruit to be harvested

based on a certain method before the robot can complete the harvesting work successfully. The processed image needs to be marked based on the 8-domain marking method, and then the marked fruit area is selected as the basic object to obtain the two-dimensional centroid coordinates. The specific equation is shown as follows:

$$\begin{cases} x = \sum_{i,j \in \Omega} \frac{i}{n} \\ y = \sum_{i,j} \frac{j}{n} \end{cases}, \quad (1)$$

where i and j are the horizontal and vertical coordinates of the pixels of the fruit image, N is the total number of pixels of the fruit image, and Ω is the set of pixels that belong to the same fruit image.

At the same time, it is also necessary to calculate the corresponding side length. Finally, we can identify the target fruit based on the effective application of the principle that the target is the closest to the image center. The specific formula for the calculation of the distance is as follows:

$$d = \sqrt{(x_o - x_c)^2 + (y_o - y_c)^2}, \quad (2)$$

where x_o and y_o are the coordinates of the centroid of the fruit and x_c and y_c are the coordinates of the center of the image.

2.3. Extraction of the Recognition Area. The target fruit information in the previous frame image has a relatively evident role. Especially for the target fruit in the next frame image, it has a relatively prominent reference role. That is to say, when the area of the next frame image is processed, we need to take the previous frame image as a basis [10]. In normal circumstances, for the purpose of acquiring the centroid coordinates of the fruit, the related work is often completed by gradually approaching the center of the image. Hence, when we complete the acquisition of the first image, the cases can often be reduced continuously through subsequent processing. After the processing described above, the image processing time will be reduced significantly, so that the overall harvesting time can be further cut, and finally the rapidness can be enhanced in the most effective way [11]. The specific steps are described as follows:

- (1) For the images acquired, after we carry out certain processing by using the relevant methods, it is necessary to identify the harvesting target fruit effectively based on the principle that the fruit essence is the closest to the image center (x_c, y_c) . Those with their own side lengths l and m should also be identified. Finally, the coordinates at the top left corner of the minimum horizontal bounding rectangle (x_t, y_t) should be determined, as shown in Figure 2.
- (2) We segment the image into four areas based on a certain method, that is, areas A, B, C, and D, and

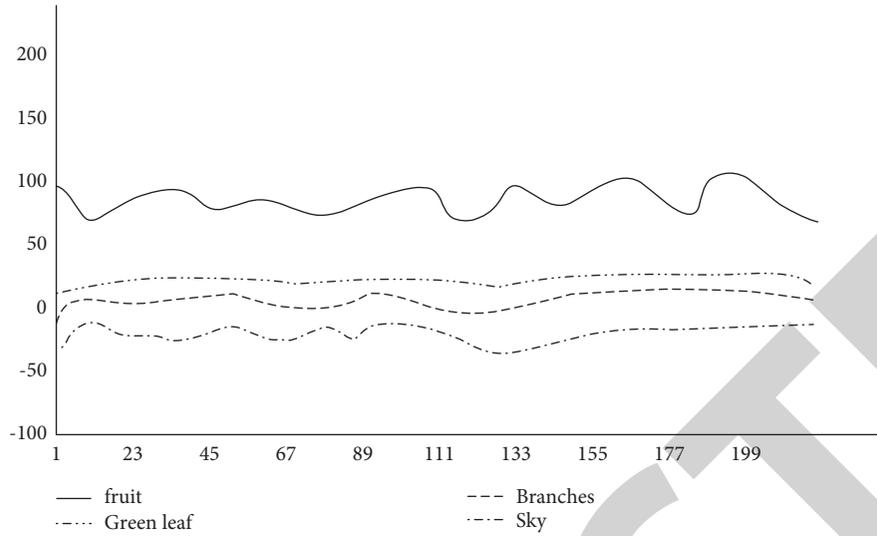


FIGURE 1: R-G color difference curve of the apple images.

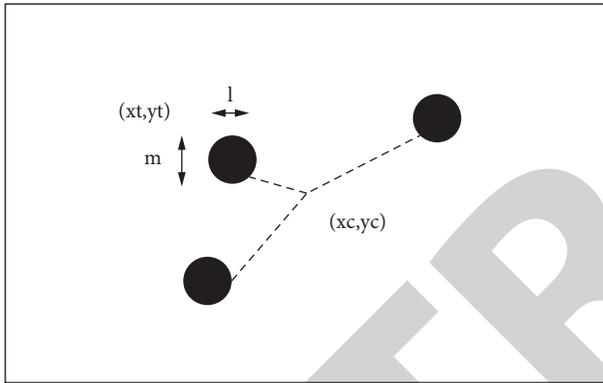


FIGURE 2: Schematic diagram of step 1.

determine which area the fruit is in through the center of the fruit and the center coordinates of the image. If it is located in area A, the coordinates (x_t, y_t) and $(x_c + l/2, y_c + m/2)$ are taken as the base points to determine the rectangular processing area, and the details are shown in Figure 3; if it is located in area B, the coordinates $(x_t + l, y_t)$ and $(x_c - l/2, y_c + m/2)$ are taken as the base points to determine the rectangular processing area; if it is located in area C, the coordinates $(x_t, y_t + m)$ and $(x_c + l/2, y_c - m/2)$ are taken as the base points to determine the rectangular processing area; if it is located in area D, the coordinates $(x_t + l, y_t + m)$ and $(x_c - l/2, y_c - m/2)$ are taken as the base points to determine the rectangular processing area.

- (3) The image is acquired, and the rectangular processing area determined in step (2) is selected as the basic object. The corresponding processing is carried out based on the method in step (1). For the space beyond the area, we can fill it with white color based on the corresponding rules, and the details are shown in Figure 4. It is certain that there are also differences.

It is necessary to convert the target fruit center coordinates obtained based on equation (1) by using the rectangular processing area coordinate system. The purpose is to convert it to the coordinate system of the acquired images. For the center of mass coordinates in the processing area where the target fruit is located, we can assume it to be (x_g, y_g) and convert it to the corresponding coordinate system of the acquired images, and the center of mass coordinates $(x_{g'}, y_{g'})$ of the target fruit can be obtained as follows:

$$\left\{ \begin{array}{l} x_{g'} = \begin{cases} x_g + x_t & (x_g \in A) \\ x_g + x_c - l/2 & (x_g \in B) \\ x_g + x_t & (x_g \in C) \\ x_g + x_c - l/2 & (x_g \in D) \end{cases} \\ y_{g'} = \begin{cases} y_g + y_t & (y_g \in A) \\ x_g + y_t & (x_g \in B) \\ y_g + y_c - m/2 & (y_g \in C) \\ y_g + y_c - m/2 & (y_g \in D) \end{cases} \end{array} \right. \quad (3)$$

- (4) It is necessary to determine the rectangular processing area in the next frame of the acquired image based on the method in step (2) and then use the method in step (3) for the related processing effectively. In this way, the continuous loop processing can be carried out until the center of mass coordinates and the coordinates of the image center are overlapped with each other.

2.4. Selection of Color Space. In the process of image processing, the commonly used color spaces, such as RGB and HSV, are diverse. For the camera input system of the vision

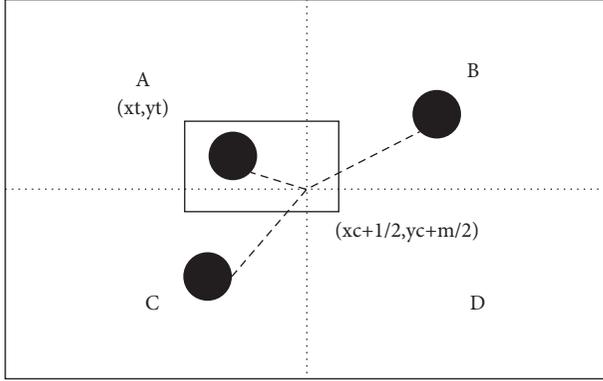


FIGURE 3: Schematic diagram of step 2.

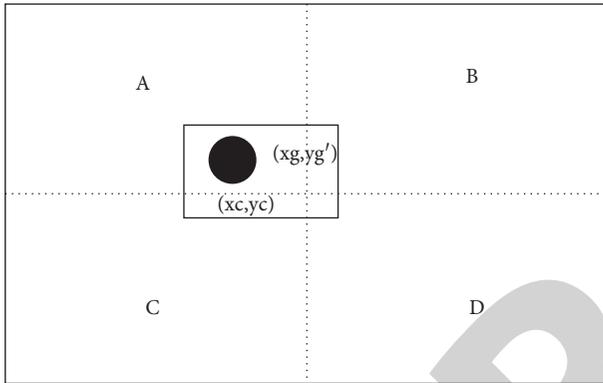


FIGURE 4: Schematic diagram of step 3.

system, it is necessary to adopt the CCD, and the most representative output mode is the RGB color space. In normal circumstances, if we need to segment a set of color graphics, the first choice of the method that comes to mind is often RGB [8, 12].

RGB space has very significant advantages. This advantage is that it is not only simple, but also intuitive. It does not require any conversion or classification in the process of application, and its speed is relatively high. However, it still has some defects. These defects are mainly manifested in two aspects as the following. Firstly, the RGB space is a color display space, which is not suitable for human visual characteristics in general. Secondly, if the conditions are different, the distribution of the measured RGB color values can present a scattered state. In this case, it will be difficult to determine the RGB value of a specific object. In addition, it is particularly prone to including some color objects that are not designated, and it is also possible to miss some objects that should be recognized [13]. In normal circumstances, if the positions are different on the game field, there may also be a huge gap in the light intensity. As a result, the RGB values of the color can vary significantly in different positions. Due to the several reasons described above, RGB is not applicable for color classification [14].

For this purpose, the RGB space to a point (r, g, b) is converted to a point (h, s, v) in the HSV space.

It is assumed that $m = \max(r, g, b)$ and $n = \min(r, g, b)$, in which $r, g,$ and b are values in the normalized RGB color space.

$$r = \frac{R}{R + G + B},$$

$$g = \frac{G}{R + G + B},$$

$$b = \frac{B}{R + G + B},$$

$$s = \begin{cases} \frac{(m-n)}{n}, & m \neq 0 \\ 0, & m = 0 \end{cases},$$

$$h = \begin{cases} 0, & s = 0 \\ 60 \frac{(g-b)}{(m-n)}, & r = m \& g \geq b \\ 360 + 60 \frac{(g-b)}{(m-n)}, & r = m \& g < b, \\ 120 + 60 \frac{(b-r)}{(m-n)}, & g = m \\ 240 + 60 \frac{(b-r)}{(m-n)}, & g = m \end{cases}, \quad (4)$$

$$v = m.$$

Given the values of $r, g,$ and b , in which $r, g,$ and $b \in (0, 255)$, the corresponding range of the conversion is as follows: $h \in (0, 360), s \in (0, 1), v \in (0, 1)$.

3. Test Results and Analysis

3.1. Image Segmentation Test. The OTSU segmentation algorithm and the fixed threshold segmentation algorithm are comprehensively compared by using a certain method. Two different apple fruit images taken under different light are selected. The details are shown in Figures 5(a) and 5(b). The image corresponding to Figure 5(a) is an image formed under strong light irradiation, and the image corresponding to Figure 5(b) is an image formed under weak light irradiation. In Figures 5(c) and 5(d), the fruit images obtained after segmentation based on a fixed threshold are shown, respectively. The segmentation threshold values of the above two are the same. Although there is a certain amount of noise from the branches and leaves in Figure 5(c), this type of noise due to branches and leaves is relatively small. In Figure 5(d), there is a more evident phenomenon of excessive segmentation. Thus, it can be observed that, with respect to the changes in light, segmentation based on the fixed threshold value is not quite adaptable. If the image is

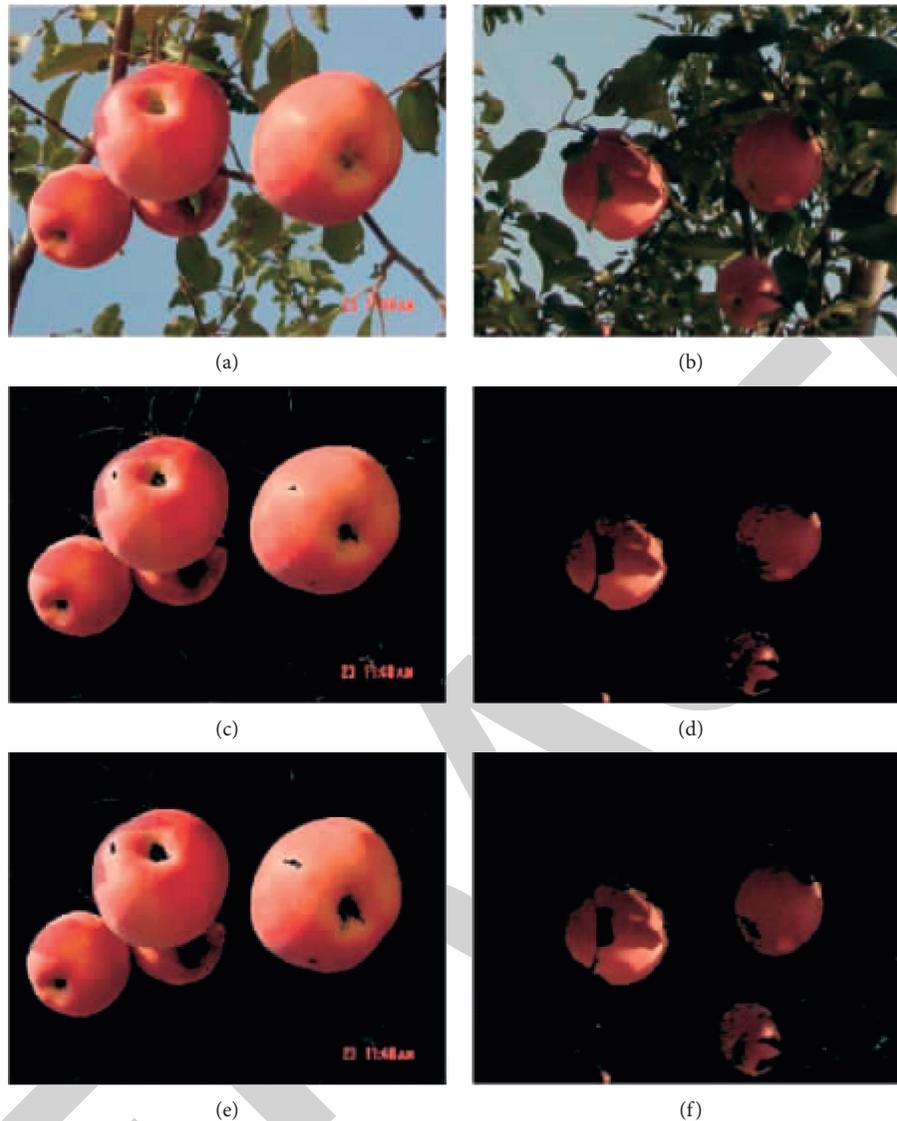


FIGURE 5: Comparison of the segmentation effects. (a) Original image 1; (b) original image 2; (c) image 1 segmented by fixed threshold; (d) image 2 segmented by fixed threshold; (e) image 1 segmented by OTSU dynamic threshold; (f) image 2 segmented by OTSU dynamic threshold.

taken under strong light conditions, then the segmentation effect is not perfect; on the other hand, if the image is taken under weak light conditions, it can also show a situation of excessive segmentation. Figures 5(e) and 5(f) show the fruit images segmented under the OTSU algorithm based on the dynamic threshold value, respectively. From the segmentation effect, it can be observed that its fruit segmentation effect is relatively good. Compared with the segmentation based on the fixed threshold value, its applicability of light is much stronger as well.

3.2. Matching Recognition Test. To verify whether the match is correct, we need to use the matching probability to carry out the corresponding test. An image of apple fruit taken in an environment with natural light is selected. In order to increase the difficulty of matching and substantially

increase the magnitude, we should choose as complex background as possible, and there should be multiple apple fruits in the image as well. In addition, we also need to select 10 apples manually, the purpose of which is to use these 10 apples as the target fruits and the template images at the same time. The details are shown in Figure 6(a). The calculated value based on equation (4), $R \sim G$ color difference value, and $2R-G-B$ color difference value are used as the image pixel gray value in this study, and relevant algorithms, such as rapid removing mean value and normalization product, are used for matching recognition effectively. It can be found through observation of Figures 6(b)–6(d) that after the RG color difference value is used, target fruits (1), (4), and (5) show matching errors. In addition, whether we use the gray scale calculated based on equation (4) or the $2R-GB$ color difference, its success rate can reach 100%.

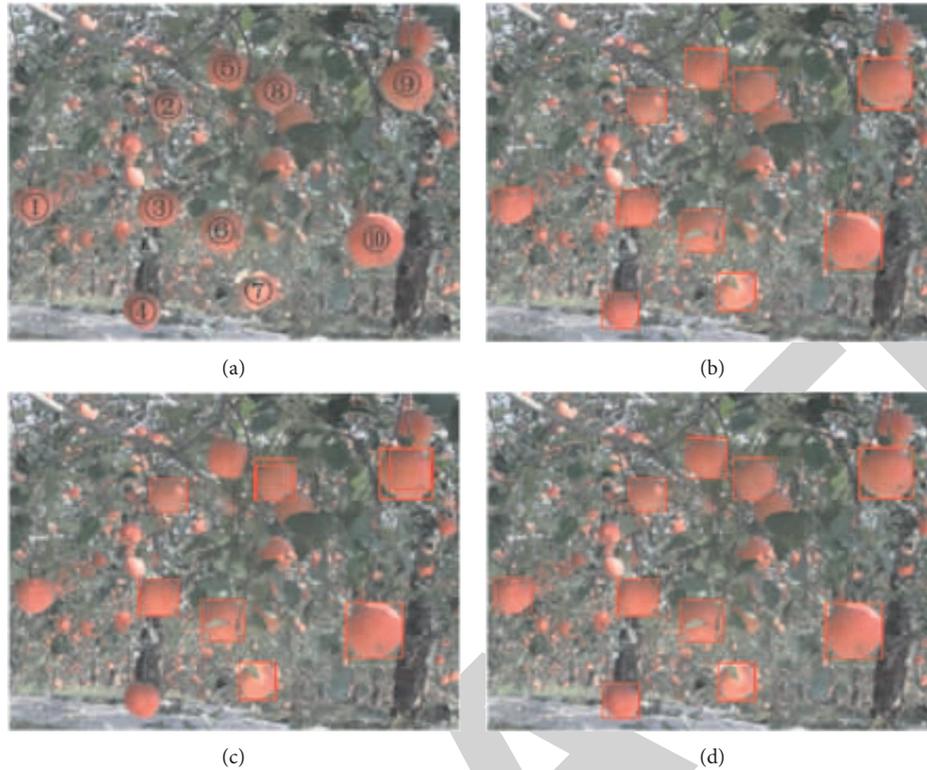


FIGURE 6: Comparison of the matching results. (a) Original image; (b) gray; (c) R-G; (d) 2R-G-B.

3.3. Interference Recognition Test. In the process of gradually approaching the center of the images, due to the different shooting angles and various lighting effects, it is possible that some changes may occur in both contrast and brightness. Hence, it is particularly necessary to carry out the matching of the algorithm test by using the relevant methods.

In general, there are two methods to adjust the brightness of images. The first method is known as the nonlinear method, and the second one is known as the linear method. When nonlinear method is used to adjust the brightness of images, it can easily lead to huge loss of image information, and the image after adjustment will look relatively flat without a solid sense of hierarchy. On the contrary, when the linear method is used to adjust the brightness of images, the image after adjustment often shows a strong sense of hierarchy, which is relatively realistic, vivid, and natural. Hence, the author adopts the photoshop as the method to adjust the brightness of the image in Figure 6 and then carries out the corresponding matching after the adjustment. There is a certain correlation between the brightness change and the matching probability. The specific relationship is shown in Figure 7. In this figure, the negative value on the horizontal axis stands for the gradual decrease in brightness, and the positive value stands for the gradual increase in brightness. It can be found through observation of the graph that the change range of brightness is within the interval of $[-35, 40]$. As long as it is within this interval, the matching probability can reach up to 100%. When the brightness adjustment is relatively large or small, a certain matching

error may occur. However, the matching probability will be reduced significantly. Since the relevant capture work is often completed within a very short time in the process of gradually approaching the image center, the changes in brightness are not particularly evident. Hence, the basic requirements can be met effectively.

For the adjustment of the contrast, the author still carries out the relevant processing by using photoshop and then performs the matching recognition to match the changes in the matching probability and the contrast. The specific relationship is shown in Figure 8. Negative value herein refers to the gradual decrease in the contrast, whereas positive value refers to the gradual increase in the contrast. It can be found through the observation of the graph that the changes in the contrast will not affect the matching recognition, and the recognition is relatively accurate in all cases.

3.4. Algorithm Comparison Test. The three algorithms described above are compared by using some methods based on certain rules to verify the rapidity of recognition.

- (1) Algorithm 1: the OTSU recognition algorithm is applied for the processing of each frame in the dynamic images.
- (2) Algorithm 2: the OTSU recognition algorithm is applied for the processing of each frame in the dynamic images. The related information of the images is used in the image processing of the subsequent frame.

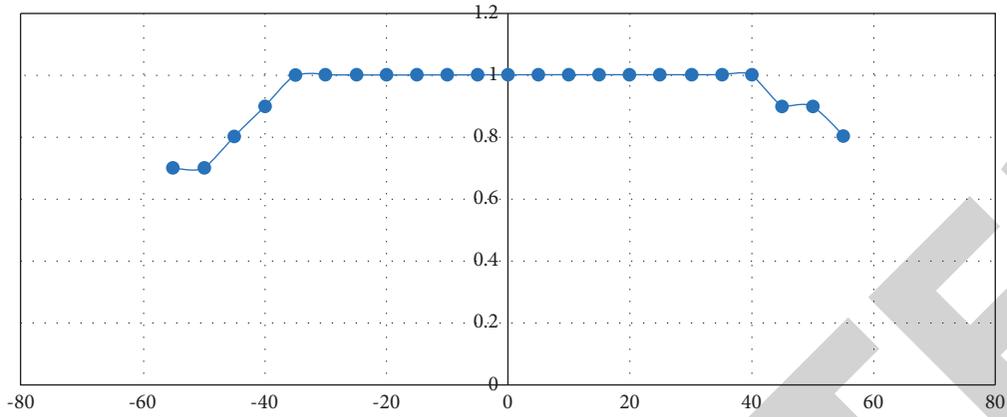


FIGURE 7: Relationship between the change in the brightness and the matching probability.

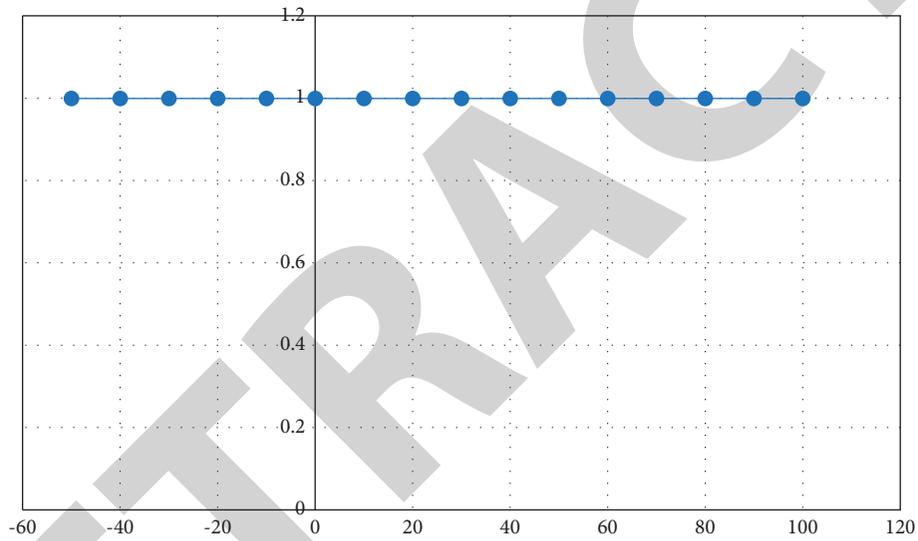


FIGURE 8: Relationship between the changes in the contrast and the matching probability.

TABLE 1: Comparison of recognition time.

Group number of the images	Algorithm 1	Algorithm 2	Algorithm 3
1	1.10	0.93	0.72
2	1.12	0.95	0.75
3	1.16	0.96	0.73
4	1.18	0.96	0.74
5	1.12	0.95	0.73
6	1.13	0.94	0.72
7	1.19	0.95	0.74
8	1.12	0.95	0.74
9	1.14	0.96	0.75
10	1.19	0.95	0.74

(3) Algorithm 3: OTSU recognition algorithm is used for the processing of the dynamic image in each frame. The related information of the image is applied in the image processing of the next frame. Subsequently, the relevant algorithm for removing the mean value and normalization is adopted effectively.

We assume that, in the process of approaching the image center, the number of dynamic images acquired by the video sensor is 4 frames, the specific pixel size is 320×240 , and 10 sets of pictures are analyzed and compared based on certain rules by using some methods. Finally, the corresponding recognition time is obtained. The specific mean time spent in

Algorithm 1 is about 1.15 seconds, and the specific mean time spent in Algorithm 2 is 0.95 seconds. It can be observed that the application of associated information can reduce the processing time by up to 17%. The time spent in Algorithm 3 is 0.74 seconds. Thus, it can be seen that the application of rapid mean value and normalization related algorithm can shorten the processing time, with a particularly obvious effect. Compared with Algorithm 1, the reduction in the processing has reached 36%. From the above comparison, it can be known that the design method adopted in this paper has great advantages and can improve the harvesting speed of the robot significantly (Table 1).

4. Conclusions

Through the real-time image information processing, the most comprehensive monitoring of the changes in the lighting of the environment can be fully implemented, and the color threshold value can also be adjusted accordingly at the same time. In this way, the image segmentation can be carried out with a certain accuracy, so that the image information thus obtained is more accurate and objective and has relative adaptability. We have obtained the implementation effects of the segmentation algorithm based on different threshold values. Compared with the old methods, the method used in this paper is superior in the effectiveness, and the recognition time is also reduced by an impressive 36%.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

- [1] D. Wang, H. Song, and D. He, "Research advance on vision system of apple harvesting robot," *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering*, vol. 33, no. 10, pp. 59–69, 2017.
- [2] S. M. Persson and I. Sharf, "Sampling-based a* algorithm for robot path-planning," *The International Journal of Robotics Research*, vol. 33, no. 13, pp. 1683–1708, 2014.
- [3] X. Ni, X. Wang, S. Wang, S. Wang, Z. Yao, and Y. Ma, "Structure design and image recognition research of a picking device on the apple picking robot," *IFAC-PapersOnLine*, vol. 51, no. 17, pp. 489–494, 2018.
- [4] H. J. Hwang, H. H. Viet, and T. Chung, "Q(λ) based vector direction for path planning problem of autonomous mobile robots," *Speech Communication*, vol. 17, no. 3–4, pp. 249–262, 2011.
- [5] D. Zhao, X. Liu, Y. Chen, W. Ji, and C. Hu, "Image recognition at night for apple harvesting robot," *Transactions of the Chinese Society for Agricultural Machinery*, vol. 46, no. 3, pp. 15–22, 2015.
- [6] S. Tamura and S. Maeyama, "Proposal of path following and arrival judgement methods using target vector for teleoperation of a mobile robot on uneven ground by image pointing," *Intensive Care Medicine*, vol. 45, no. 3, pp. 183–189, 2011.
- [7] Y. H. Kim, J. B. Park, W. S. Son, and T. S. Yoon, "Modified turn algorithm for motion planning based on clothoid curve," *Electronics Letters*, vol. 53, no. 24, pp. 1574–1576, 2017.
- [8] Y. A. Huang, H. Wu, H. Liu, and Z. Yin, "Trajectory planning of space robot system for reorientation after capturing target based on particle swarm optimization algorithm," in *Proceedings of the 10th International Conference, ICIRA 2017*, Wuhan, China, August 2017.
- [9] S. Tang, D. Zhao, W. Jia, C. Yu, J. Wei, and C. Ruan, *Feature Extraction and Recognition Based on Machine Vision Application in Lotus Harvesting Robot*, Springer, Cham, Switzerland, 2015.
- [10] K. K. Pandey and D. R. Parhi, "Trajectory planning and the target search by the mobile robot in an environment using a behavior-based neural network approach," *Robotica*, vol. 38, no. 9, pp. 1–15, 2019.
- [11] H. Z. Zhao, G. L. Yang, and C. Y. Chen, "Using 3D matching for picking and placing on UR robot," *Applied Mechanics and Materials*, vol. 870, pp. 289–294, 2017.
- [12] C. Liao, Y. Liao, and J. Xie, "Obstacle avoidance trajectory planning of loading robot based on improved RRT algorithm," *International Core Journal of Engineering*, vol. 6, no. 5, pp. 209–213, 2020.
- [13] Y. Qu and Z. Liu, "Dimensionality reduction and derivative spectral feature optimization for hyperspectral target recognition," *Journal for Light and Electronoptic*, vol. 17, no. 3–4, pp. 249–262, 2017.
- [14] H. Kojima, "Trajectory planning of cp control flexible robot arm using genetic algorithm," *Transactions of the Japan Society of Mechanical Engineers*, vol. 68, no. 670, pp. 1784–1790, 2017.