A Recognition Scheme Based on K-means Feature Clustering for Obscured Apple Object

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Abstract. At present, the recognition effect of the mature apple automatic picking vision system is not ideal. To solve this problem, this paper proposes a method based on K-means feature clustering for the recognition of the occluded apple object. That is, using K-means algorithm to cluster the image in L*a*b color space, and using the *a component to distinguish the object from the background to improve the segmentation accuracy. Then, the real contour of the segmented object is extracted by using the convex hull algorithm. Finally, the least squares algorithm is used to reconstruct the extracted object contour. The experimental results show that the proposed scheme can accurately segment and recognize the occluded apple object, which lays a solid theoretical foundation for the application of apple automatic picking vision system to achieve precise picking.

1. Introduction

As one of the main fruits in our country, the traditional apple picking is done by hand, which costs a lot of labor and takes a long time. Therefore, the automatic apple picking has become a hot issue for scientists. The phenomenon of apple being covered by leaves is very common in the natural growth state, which makes it difficult for the automatic picking system to recognize the object, and then affects the efficiency of apple picking[1].

As early as last century, experts and scholars at home and abroad began to study the recognition algorithm of occluded fruits in natural environment, and achieved some results. For example, Italian scientist Buemi[2] (1995) converted RGB of image color space into HIS, and used saturation and hue to segment and recognize citrus image object; Weikuan Jia et al.[3] (2015) proposed K-means clustering segmentation and neural network method to recognize apple object; Haobo Hu[4] (2017) combined morphology, contour extraction and sorting, and circle fitting to recognize the occluded apple object. However, the performance of the current algorithm is not high enough, and the reconstruction of the missing contour cannot be achieved well.

In view of the above analysis, this paper proposes a scheme of occluded apple object recognition based on K-means feature clustering. Firstly, the image is filtered and denoised by median filtering; then, the image is transformed from RGB color space to L*a*b color space, and the apple object is segmented by K-means clustering algorithm. The *a component, which contains red color and is not affected by brightness, is used as the feature component of the object class to overcome the interference from brightness factor and the other colors similar to the object color of mature apples. Secondly, the Canny edge detection operator and convex hull algorithm are used to extract the object contour and remove the false contour. Finally, the least square algorithm is used to reconstruct the extracted object contour and realize the recognition of the occluded apple object.
2. Image filtering
The acquired image often has noise, so the first step is to filter the image. According to the noise characteristics of the image in this paper, two-dimensional median filter with better effect of eliminating salt and pepper noise is selected to denoise the apple image.

The median filtering effects of different sizes of templates are simulated. The results are shown in figure 1, where (a)~(d) denotes the original image, the filtering effects of 3*3 template, 5*5 template and 7*7 template, respectively. Through observation, it can be found that the 5*5 template can filter out the isolated noise points in the image, and the edge details are not too blurred. Therefore, the 5*5 template is selected to filter the apple image.

![Figure 1. Simulated image of different size template filtering effect.](image)

3. Apple object segmentation based on feature clustering

3.1 Selection of color space
Color feature is a very important feature of objects, and it is also the key feature to distinguish background and object in this paper. The R, G and B components of the most common RGB color space model contain brightness information, which is easy to be affected by illumination when segmentation. In the L*a*b color space model, the component L represents brightness, the component *a represents redness and greenness, and the component *b represents yellowness and blueness[5]. Therefore, it is considered that transform the image into L*a*b color space, and distinguish the object from the background by using the component *a which contains the red color of mature apples and is not affected by the brightness component L.

3.2 Image segmentation based on K-means feature clustering
K-means clustering algorithm is an unsupervised learning clustering algorithm[6]. The basic idea is:

- K samples were randomly selected as initial clustering centers.
- Calculate the Euclidean distances between all the sample data and K clustering centers, and classify each sample data into the cluster where the nearest clustering center is located.
- Recalculate the clustering centers of each cluster (take the average), and redistribute the sample points to each cluster.
- Repeat the last step until the cluster centers calculated by two adjacent times are all identical or change very little, and the classification ends.

Since the apple image includes the apple object and background areas such as leaves, branches, land and sky, the initial number of clustering centers k=2 or k=3 is considered to cluster the apple image. The results are shown in figure 2, where graph (a) shows k=2, graph (b) shows k=3.

![Figure 2. Clustering results of different cluster centers.](image)
From the clustering results of figure 2, it can be seen that K-means clustering algorithm in L*a*b color space can overcome the interference of image brightness factor and approximate characteristic color. When k=2, the segmentation effect is better. And considering the speed of the algorithm, the initial clustering number is set as 2.

Then, the bwareaopen function in MATLAB is used to remove the small connected areas in the upper left corner and the lower left corner for edge detection and contour extraction. The processing results are shown in figure 3.

![Figure 3. Result of removing small area connected domain.](image)

4. Contour extraction and reconstruction of apple objects

4.1 Object true contour extraction based on convex hull theory

Firstly, Canny operator is used to detect the edge of the target and the result is shown in figure 4. And it can be seen that the apple object contour extracted contains the edge contour (pseudo-contour) of the leaf. In order to extract the true contour of the object accurately, the pseudo contour should be removed based on the convex hull theory.

Convex hull is the smallest convex set that contains all points in the set. Convex hull is the boundary of these point sets, and the vertex of convex hull must be the point of the point set[7]. Because the object contour of apple is quasi-circular, the coincidence between convex hull and real contour is very high. So the steps of eliminating pseudo-contour are obtained:

- Extracting the cam of the object contour.
- Tracking the convex hull boundary in eight neighborhoods and calculating the position serial numbers of contour points corresponding to the vertices of each convex hull.
- Calculate the Euclidean distance between adjacent contour points according to numbers.
- Taking the average of all distances as threshold. If the distance between the two vertices of convex hull is less than the threshold value, the contour is considered as a pseudo-contour and is removed; otherwise, it is considered as the real contour of the object.

The outline of the apple treated by the above method is shown in figure 5. It can be seen that the false contour has been completely removed and the true contour has been preserved to the maximum extent.

4.2 Reconstruction of real contour of object based on least square algorithms

As can be seen from figure 5, the real object contour is not complete. Therefore, the least square algorithm is used to reconstruct the contour. The algorithm fits the points on the contour into circles by the mathematical optimization method of minimizing the sum of squares of errors[8].

The contour reconstruction result is shown in figure 6. The blue line is the real contour of the reconstructed object. It can be seen that the real outline of the apple object can be fitted by the least square algorithm, and the outline is complete and smooth, which accords with the characteristics of the object.
5. Experimental verification and results analysis

5.1 Experimental verification

In this paper, 20 occluded apple images are selected randomly, and the images are denoised, segmented, contour extracted and contour reconstructed using the proposed scheme (the example results are shown in figure 6).

In order to more accurately illustrate the effect of the scheme recognition and reconstruction, recognition coincidence and recognition error are introduced to evaluate the results. Their expressions are shown in formulas (1) and (2).

$$ o = \frac{S \cap S}{S} \times 100\% $$

$$ \delta = \frac{|S_{i} - S|}{S} \times 100\% $$

The recognition coincidence and recognition error of 20 final result images are counted. The results are shown in table 1.

| Apple image number | True area (pixel) | Recognition area (pixel) | Overlap area (pixel) | Recognition coincidence | Recognition error |
|--------------------|------------------|--------------------------|---------------------|-------------------------|------------------|
| 1                  | 122487           | 118168                   | 109025              | 89.01%                  | 3.53%            |
| 2                  | 78513            | 77279                    | 76374               | 97.28%                  | 1.57%            |
| 3                  | 57955            | 56390                    | 55981               | 96.59%                  | 2.70%            |
| 4                  | 144362           | 143837                   | 141011              | 97.68%                  | 0.36%            |
| 5                  | 64380            | 65326                    | 62753               | 97.47%                  | 1.47%            |
| 6                  | 74829            | 76252                    | 71323               | 95.31%                  | 1.90%            |
| 7                  | 48395            | 46298                    | 45034               | 93.06%                  | 4.33%            |
| 8                  | 62318            | 63187                    | 61952               | 99.41%                  | 1.39%            |
| 9                  | 138483           | 136235                   | 133751              | 96.58%                  | 1.62%            |
| 10                 | 26352            | 29194                    | 24007               | 91.10%                  | 10.78%           |
| 11                 | 85830            | 85087                    | 84857               | 98.87%                  | 0.87%            |
| 12                 | 46341            | 44239                    | 43195               | 93.21%                  | 4.54%            |
| 13                 | 89232            | 95458                    | 85908               | 96.27%                  | 6.98%            |
| 14                 | 64900            | 66076                    | 63225               | 97.42%                  | 1.81%            |
| 15                 | 74306            | 78277                    | 73523               | 98.95%                  | 5.34%            |
| 16                 | 95635            | 94113                    | 93279               | 97.54%                  | 1.59%            |
| 17                 | 53929            | 55832                    | 52419               | 97.20%                  | 3.64%            |
| 18                 | 93272            | 100197                   | 90884               | 97.44%                  | 7.42%            |
| 19                 | 46791            | 47305                    | 44932               | 96.03%                  | 1.10%            |
| 20                 | 129864           | 120147                   | 115803              | 89.17%                  | 7.48%            |

Average value: 95.78% ± 3.52%
5.2 Results analysis

As can be seen from figure 6, this scheme can accurately recognize apple objects, and retain the edge information of the original object to a great extent. The recognition effect is ideal.

As can be seen from table 1:

- The average recognition coincidence of 20 randomly selected apple objects is 95.78%, and the average recognition error is 3.52%. The recognition coincidence of most apple objects is higher than the average and the recognition error is lower than the average. The results show that the proposed method not only has high segmentation accuracy, but also can accurately identify the apple object covered by leaves, and the performance of the algorithm is stable.

- The recognition coincidences of apple objects number 1 and number 20 are low. The reason may be that the two images have larger area covered by leaves and more real outline missing, which leads to poor fitting results.

- The recognition errors of apple objects number 10, number 18 and number 20 are large. It is observed that there are other mature apples in the background of these three images, which are not distinguished when they are recognized, so they are disturbed to a certain extent.

6. Conclusion

In order to realize the accurate recognition of the apple object occluded by the leaves by the automatic picking vision system, this paper proposes a recognition scheme based on K-means feature clustering combined with Canny edge detection, convex hull algorithm and least square algorithm. The experimental results show that the proposed scheme can improve the segmentation accuracy of the occluded apple object, realize the accurate extraction of the true contour of the object and the accurate reconstruction of the missing contour, thus realize the accurate recognition of the occluded object, and provide theoretical reference for the application of the automatic picking vision system to achieve precise apple picking.

References

[1] Shen T. (2016)Research on fast dynamic recognition and location of overlapping fruits of apple picking robot. Zhenjiang: Jiangsu University.
[2] Buemi F.E., Massa M., Sandini G. (1995)A robot system for greenhouse operations. In: 4th Workshop on Robotics in Agriculture. IARP Tolouse. pp. 172-184.
[3] Jia W.K., Zhao De'an, et al. (2015) K-means and ga-rbf-lms neural network recognition of apple fruit picked by robots. Journal of Agricultural Engineering, 31: 175-183.
[4] Hu H.B. (2017)Research on recognition and location of apples based on binocular vision in natural environment. Qinhuangdao: Yanshan University.
[5] Bulanon D.M., Burks T.F., Alchanatis V. (2010)A multispectral imaging analysis for enhanced citrus fruit detection. Environmental Control in Biology, 48: 81-91.
[6] Li H.R. (2014)Improvement and application of K-means clustering method. Harbin: Northeast Agricultural University.
[7] Song H.B., He D.J., Pan J.P. (2012)Object recognition and location method for occluded apples based on convex hull theory. Journal of Agricultural Engineering, 28: 174-180.
[8] Xia X. (2018)A computer vision-based method for detecting and locating apple fruits. Beijing: Chinese Academy of Agricultural Sciences.