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Research on Apple Recognition and Location in Automatic Picking Robot

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Abstract: This paper studies the object recognition and location of apple picking robots, improves the picking efficiency, and has wide application value. Apple Abstract solves three problems: the identification of apples, the judgment of apple maturity and the distance location of apples and picking devices. In terms of apple recognition, this paper divides Apple's recognition into overlapping and non-overlapping regions. For the case of no overlapping area, firstly, the original image acquired is subjected to color space change, the contrast of the red component is increased, and then the apple is identified by the morphological processing and the Hough circle detection method. For the case of overlapping regions, the apple can be identified by curve fitting method and then according to the Hough circle detection method. In the judgment of apple maturity, this paper determines the mature fruit by comparing the color pixel values.

Keywords: Maturity recognition; overlap recognition; distance location.

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1. PREFACE

The research on computer vision involves many fields, especially in the application of artificial intelligence and agriculture. The fruit and vegetable picking robot needs to rely on the platform of computer vision to realize the identification tracking of the target fruit and the processing of the acquired image. Due to the interference of external environmental and climatic factors, the difficulty of fruit identification and tracking will increase. In the actual environment, the fruit will overlap, and the premise of positioning and ranging is the accurate identification of the target fruit, so the fruit with defects in pixels is needed. Carry out recovery. Considering the subsequent picking problem, the ranging between the target fruit and the camera is also a problem to be studied. Li Zhenyu et al [1] adopted the histogram equalization method to deal with the apple image obtained when the outdoor illumination is uneven and highlights the apple color by improving the contrast; Miao Zhonghua et al. [2] uses the watershed algorithm for overlapping fruits. Obtaining the edge of a single target; Jidong et al [3] also adopts the watershed algorithm for distinguishing backgrounds; Lv Jidong et al. [4] adopts SSD depth algorithm for fruit recognition, and the existing papers have improved the recognition and three-dimensional positioning methods of overlapping apples. There has not yet proposed a method for judging the maturity of apples.

In this paper, we use the apples grown under the natural conditions as the research objects. OpenCV image processing technology was used to study the identification and ripening of mature fruits.

2. MAIN RESEARCH QUESTIONS

Now the fruit industry has become a pillar industry for farmers to increase their income in many areas. The mechanized development of orchard can reduce the labor intensity of fruit farmers, save labor costs and improve economic efficiency. This paper studies the object recognition and positioning of object picking robots, mainly the recognition of apple, the judgment of apple maturity and the distance positioning of apple and picking device. The recognition mainly focuses on the identification of overlapping apples and apples with overlapping areas. The color of the pixel values is used to determine the mature fruit. A similar triangle relationship between the OpenMV camera and the apple is used to derive the apple from the machine distance.

3. IDENTIFICATION PROCESS AND ALGORITHM RESEARCH

3.1 Apple's identification process

Figure 1 shows the specific process of overlapping apple recognition. The identification of non-overlapping apples simplifies the curve fitting steps.

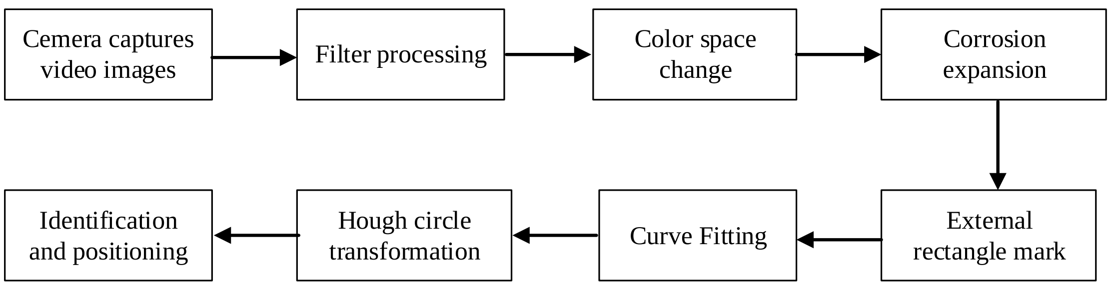

Fig 1. Flow chart of apple recognition process

3.2 Single and overlapping apple identification methods

Apples grown in the natural environment are affected by various factors during the growth process, which makes the surface of the collected apple dark or bright, which causes a certain degree of interference to the recognition. In this paper, in the processing of Apple recognition, a variety of methods are used to improve its accuracy. The method is as follows:

First, we can convert the RGB color space to the YCrCb [5] color space, and separate the Cb channel as the basis for image processing.

Mature apples are generally red in color. The YCrCb color space will highlight the red characteristics of mature apples and increase the difference from other colors. Because of the biggest difference between apple and background in Cb channel, it is easier to process and segment them, improve the recognition rate.

Algorithm between YCrCb and RGB color space:

$$\begin{bmatrix} Y \\ C_r \\ C_b \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

Second, we can use the method of Minimum circumscribed rectangle marking method [6]. The minimum circumscribed rectangle is also translated as the minimum bounding rectangle, that is, the target to be detected is segmented by a minimum rectangular frame; first, convex detection is performed, and a boundary rectangle is made with the largest range of the convexity as a boundary. In this paper, the rotating boundary rectangle is used, that is, the rectangular boundary can be parallel to the two-dimensional coordinate axis, and the circumscribed rectangle with the smallest area can be found and segmented.

The Hough transform has a large parameter space and takes a long time. If the whole picture is directly processed, a huge amount of computation is required, and the effective part is only the apple area. Therefore, to simplify the operation and increase the operation rate, the external rectangle mark method is effective for Apple. Part of the area is marked.

Third, we can use the curvature feature of the contour to fits the specify curvature. Since the images recognized by the camera are two-dimensional, they cannot be regarded as a single separated apple from different angles. Therefore, it is very difficult to identify overlapping apples based on the identification method of a single apple.

According to the idea of target curvature reconstruction in the occlusion of the branches and the reconstruction of the apple model [7], the method is applied to the overlap of apples. The contour of the apple is a smooth arc. For the smooth zone, the curvature changes little. In the smooth zone, the curvature changes greatly, and the change of the curvature reflects the change of the contour line. Therefore, the peripheral contour is identified by calculating the curvature, and the curve is fitted to the missing edge.

Finally, we can use the gradient Hough circle transform algorithm for apple recognition, adjust the upper and lower limits of the resolution and radius threshold to achieve the best recognition effect, and finally return to the center of the circle to achieve positioning and recognition.

3.3 Determination of apple maturity

There is no uniform standard for the maturity of apples. This paper proposes a more reasonable judgment method for mature apples with red color. The maturity of apples is reflected in the overall color of the fruit and the degree of red. The development trend is shown in Figure 2.

Apple growth curve function:

$$f(x) = a_0 + a_1 \times \sqrt{x} \tag{2}$$

Apple growth curve: The color change is faster in the early growth stage and gradually slows down in the late growth stage, so that it does not change, and the slower growth stage is a non-linear curve.

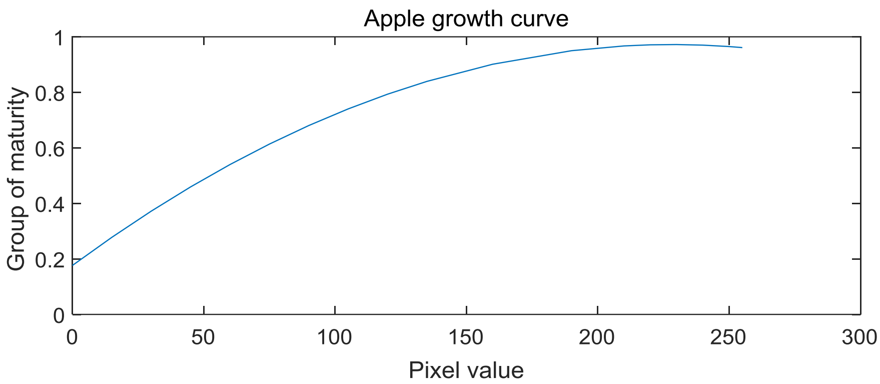

Fig 2. Apple growth curve

For the judgment of maturity, we firstly use the method of pixel value selection to divide the apple surface in the line of sight into N parts (for example, 3×3), and obtain the pixel values in each small part respectively, and calculate the weight by the weight method. Each pixel value accounts for the proportion of maturity. Finally, the average pixel value is calculated by the weighted average method. Comparing with the setting value of the pixel value that the standard mature apple value. If the difference is within ±5%, it is judged to be mature. Otherwise, it is judged to be immature.
The proportion of apples in the same area as the mature situation:

C	D	C
D	D	D
C	D	C

Fig 3. Specific gravity distribution in different regions of apple

$$a = \begin{cases} A & n \in C \\ B & n \in D \end{cases} \tag{3}$$

$$4C + 5D = 1 \text{ and } D > C \tag{4}$$

The calculation method of Apple average pixel value:

$$P_A = \sum_{i=1}^{n} \frac{a_i \times c_i}{N} \tag{5}$$

The value of C represents the pixel value, a represents the specific gravity, n represents the region, the value of C and D respectively represent different regions of the apple surface, and the value of A and B respectively represent the proportion of the maturity of the different regions.

Due to the problem of the direction of the sun, it may appear that the growth condition on one side is better than that on the other side, and the multi-angle and multi-faceted judgments can be used for the actual operation.

3.4 Apple and camera distance positioning problem

In the process of picking apples, ranging positioning is a very important problem. Different from the method that the Li Hongli [8] used, the 3-point deterministic circle algorithm is the center, and the other parts of the image are used as the auxiliary distance to determine the distance. This study uses a similar triangle relationship between the OpenMV camera and Apple to derive the distance of the apple from the machine, which is more intuitive and concise.

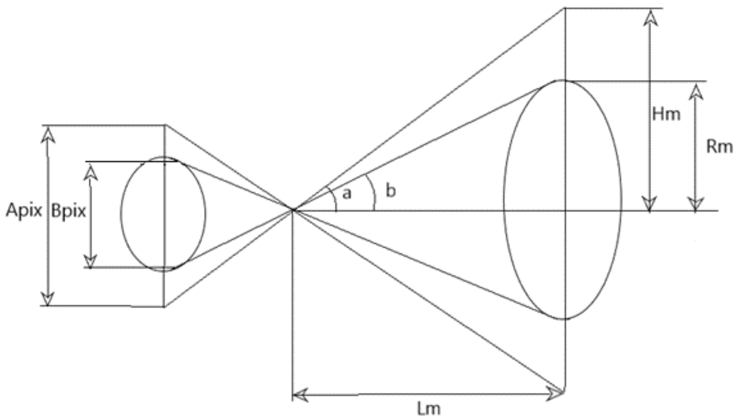

Fig 4. Similar triangles in camera

From the geometric relationship in the camera, the following formulas can be obtained:

$$\tan(a) = \frac{Apix}{2L} \tag{6}$$

$$\frac{\tan(a)}{\tan(b)} = \frac{Rm}{Lm} \tag{7}$$

$$\tan(b) = \frac{Bpix}{2L} \tag{8}$$

$$\tan(\mathrm{b}) = \frac{Rm}{Lm} \tag{9}$$

From the above equation, we can draw a conclusion as shown in formula (5):

$$Lm \times B\mathrm{pix} = \frac{Rm \times Apix}{tan(a)} \tag{10}$$

The actual length is inversely proportional to the pixels in the camera:

$$\text{Distance} = \frac{\text{A Constant}}{\text{Diameter Pixel}} \tag{11}$$

4. EXPERIMENTAL RESULTS

4.1 Results of a single apple experiment

In the process of apple identification, the first thing is to recognize whether the fruit is mature. Through the processing of the color space in the early stage, the contrast between the mature apple and the surrounding environment is increased, and then the filter is used for noise reduction and binarization. The edge contour is processed by the sobel operator, and (X, Y) are two channels and then combined. The combination of these two channels improves the accuracy of the contour drawing. The recognition rate of apples is shown in Table 1. The following statistical results show that the recognition rate of a single mature apple is about 92%.

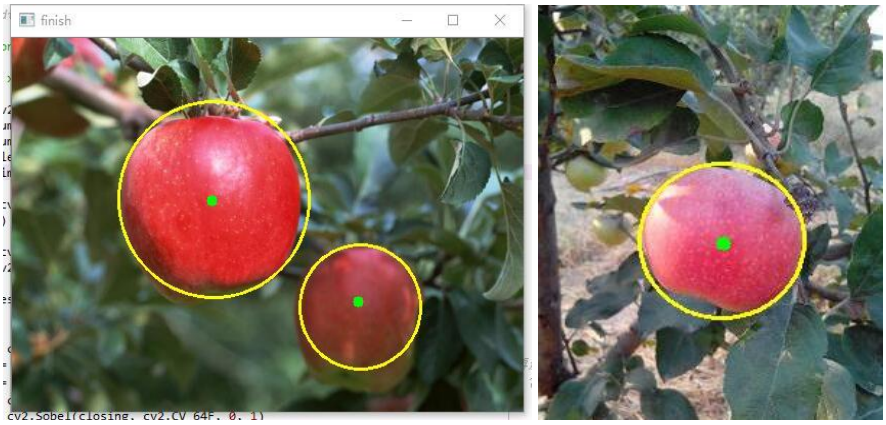

Fig 5. Single mature apple recognition map

4.2 Experimental results of overlapping apples

For the apple with overlapping phenomenon, part of the apple target part is occluded, only part of the outline can be obtained. To get the complete outline, it is necessary to add the image fitting processing to the edge vacant part based on the single apple recognition. Using the method of minimum circumscribed circle, the curve is used to reconstruct the edge, and then the method of Hough circle transformation is used to select the apple. The coordinates of the apple are finally realized to realize the recognition of the overlapping apples, and the overlapping mature apple recognition effect and the sample recognition rate shows that when the fruits overlap, the recognition rate of the uncovered fruits is higher than the recognition rate of the occluded fruits.

Fig 6. Overlapping mature apple recognition map

4.3 Apple recognition accuracy rate

Table 1. Apple recognition statistics

Apple	Number of samples	Number of identified	Number of identified
Non-overlapped apple	50	46	92%
Overlapped apple	50	44	88%

The success rate did not reach a very ideal state, because the number of apples in the orchard was huge, and the apple in the distance in the background would interfere with the recognition of the target apple.

4.4 Experimental results of Apple ripening

Table 2. Apple maturity identification table

Experimental environment	Number of samples	Number of identified	Recognition rate %
In a bright environment	50	47	94%
In a dark environment	50	41	82%

In this study, when the maturity was 0.8, the apple to be considered as a mature apple. Due to the different light intensity at different times, different contrasts are formed on the surface of the apple, which may cause interference when judging whether the apple is mature. In bright conditions, the contrast is outstanding, and the recognition rate of the apple is higher.

5. CONCLUSION

In this paper, the problem of inaccurate recognition of apple overlap is solved by curve fitting and edge reconstruction. The distance between Apple and the machine is calculated by the similar triangle relationship between OpenMV camera and Apple. The average is calculated by weighted average in maturity judgment. The pixel value is judged by the comparison with the set pixel value. The experiment proves that the method is feasible.

The first innovation is the use of OpenCV image processing technology; the second is the use of YCrCb color space; the third is the flexible use of multiple image processing methods, such as Kmeans clustering algorithm to segment images, Sobel operator in both directions merging, curve fitting, etc.

This article basically achieves the expected goals, but because of the real-time field picking of apples, it will be affected by the climate, especially when the wind is very strong, it will have a great impact on the identification of the fruit; secondly, when the overlap is more than 50% Apple's recognition efficiency will be reduced, resulting in the inability to fully identify, and has not found a good solution to this problem.

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