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Structure Design and Image Recognition Research of A Picking Device on the Apple Picking Robot

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Abstract: Picking robot is the inevitable trend of the development of orchard harvester technology in the future. However, automatic apple picking technology is difficult to achieve because of uncertainty in distribution, inconsistent maturity, and uneven quality and other issues. It is hard to locate the position of apples accurately. Therefore, after summarizing the advantages and disadvantages of apple harvesting technology at laboratory and abroad, a picking device was designed. The device is based on the purpose of distinguishing the maturity of apples and consists of shell, cutting device, power device. It can achieve efficient and rapid fruit picking and more accurate differentiation of maturity. For other similar spherical fruit also has some applicability.

Keywords: Apple picking robot; picking device

1. INTRODUCTION

Apple is one of the main fruits produced in China. In 2002, China's apple production was 19.24 million tons, and apple production accounted for 27% of the country's fruit production, which was far higher than the proportion of apples in the world. In the face of such a huge apple production, the development of automated picking technology has very important practical significance. The picking device is an important executing component for picking robots to achieve picking operation. The picking device will directly affect the picking efficiency and quality of the picking robots. Because of the distribution characteristics of the apple tree, it is difficult to accurately position the fruit. Improper picking will cause problems such as scratching the surface of the fruit and excessive landing, so as to reduce orchard production and income. For practical picking problems, summarizing the advantages and disadvantages of picking robots at home and abroad, this paper designed an orchard robot picking device, and we received good results. The picking device is also suitable for other similar spherical fruits.

2. OVERALL PLAN

The picking device is comprised of the shell, the cutting device, the power device. The shell is made according to the size of the actual apple, leaving enough margin to ensure that the apple can enter smoothly; The cutting part is driven by the power device and can complete the rotation action with the power device; The servo is selected as the driving part of the cutting device; There is a hole opened at the bottom of the shell for collecting. The main structure of the picking device is shown in Figure.1.

2.1 The Shell

Taking in account the characteristics of apples' appearance, apples will inevitably drop down due to scratching of branches or other fruits during the picking work. Therefore, It is necessary to make a protective shell for the picking device. This ensures that apples can fall into the hole relatively accurately. Under the condition of the strength requirements, the shell of the picking device is made of aluminum alloy or engineering plastic to reduce the weight of the device.

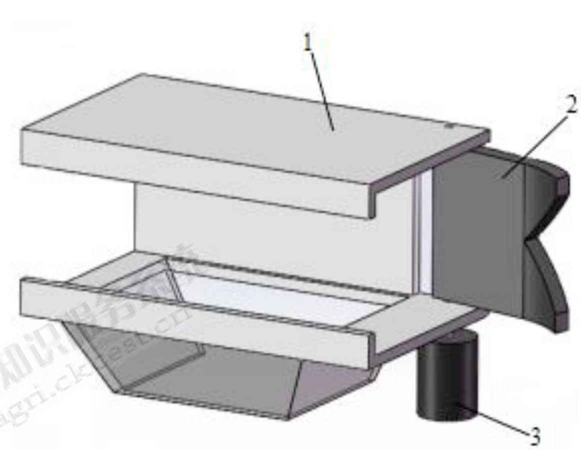

Fig. 1. The main structure of the picking device. 1. The shell. 2. The cutting device 3. The power device.

2.2 The Power Device

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Stepping motor and servo can both be selected as the power device. We compared their performance individually.

Stepping motor (as shown in Figure 2.) is open-loop control motor, which converts electrical pulse signals to angular or linear displacements. In the case of non-overloading, the speed of the motor and the stop position depend only on the frequency of the pulse signal and the number of pulses, but are not affected by loading changes. When the stepping driver receives a pulse signal, it drives the stepping motor to rotate in a setting direction by a fixed angle.

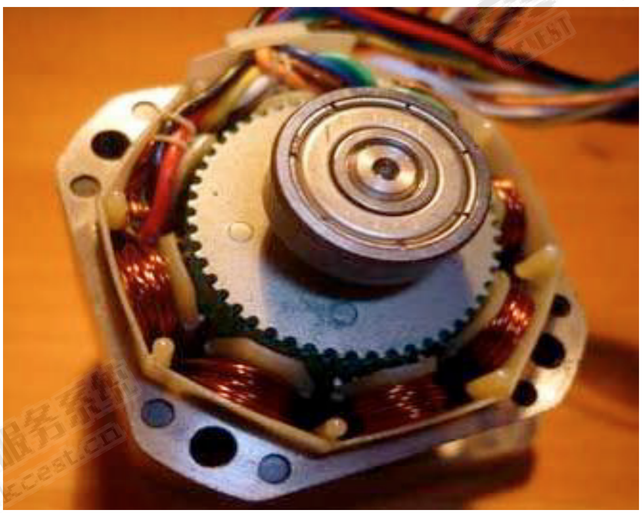

Fig. 2. The internal structure of the stepping motor.

From the structure point of view, servo (as shown in Figure.3.) is a small DC motor, together with sensors, control chips and reduction gear sets, packing into an integrated housing. Servo is a position (angle) servo driver for control systems that require constant change and maintenance of angle. The working principle of servo is that the receiver sends a signal to servo, and the direction of rotation is determined by the IC on the circuit board. Then the motor starts to rotate, and the power is transmitted to the swing arm through the reduction gear, at the same time the signal is sent back by the position detector to determine if it has reached the position.

After comparing the performance of stepping motor and servo, we found that it is hard for stepping motor to obtain large torque and stepping motor will be unstable when it is rotating rapidly. Therefore, we selected servo as the power device.

2.3 Working Process

The vision system takes pictures of the apple tree and processes the images. Based on the position obtained by the vision system, the robotic arms move the picking device to the picking position. Apples enter the picking device from the opening side, and the other side will be blocked by the cutting device. The servo drives the cutting device to the desired position to cut off the fruits. Fruits will fall into the hole at the bottom of the shell. Under the protection of the shell, the picked fruits will not fall to the ground. This will greatly improve the picking efficiency and effectiveness.

3. IMAGE PROCESSING

The vision system is an important part of the apple picking robot. One of the most critical steps in the picking task is the identification and positioning of the apple target.

The apple picking robot vision system generally consists of an image acquisition part, an image processing analysis part, and an output or display part. The main task of the apple picking robot vision system is to obtain apple digital images, perform image processing on the acquired images, identify and position apple targets.

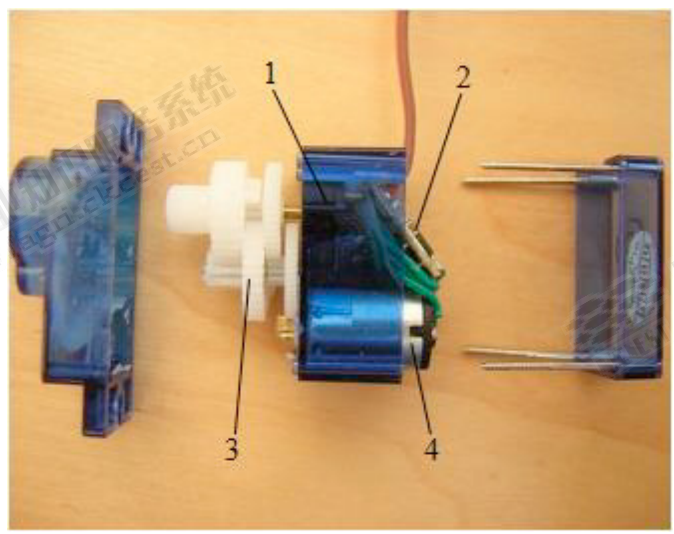

Fig. 3. The structure of the servo. 1. Position feedback potentiometer. 2. Control board. 3. Reduction gear sets. 4. DC motor.

Every step in the image processing has a variety of methods, selecting an appropriate method will greatly improve the efficiency of the image processing.

3.1 The RGB Color Space

In the natural environment, under the influence of the growth of the fruits, various position and posture, and position of the image acquisition system, the collected images of apples are varied. The images can be summarized as the following types (as shown in Figure.4.), including a single unobstructed fruit, the blocked fruit, overlapping fruit and so on.

Fig. 4. Different postures of the fruits under natural light

The color space, also known as the color model, enables the digital representation of colors based on this model. Color is sensitive and plays a key role in image processing. The color space describes all the colors by several components, it can also be said that the colors are explained in a more acceptable way based on certain standards. All the colors in the image can perform self-expression in a single point form with the help of color space.

The RGB color space is the most commonly used color model. Based on the three basic colors of red, green, and blue, they can be superimposed to different degrees, and more than 16 million different colors can be synthesized. The RGB color space uses a unit-length cube to represent colors. The eight common colors of black, blue, green, red, yellow, and white are located at the eight vertices of the cube respectively. Black is usually placed at the origin of the three-dimensional rectangular coordinate system. Red, green and blue are placed on three axes respectively, and entire cube is placed in the first octant (as shown in Figure 5).

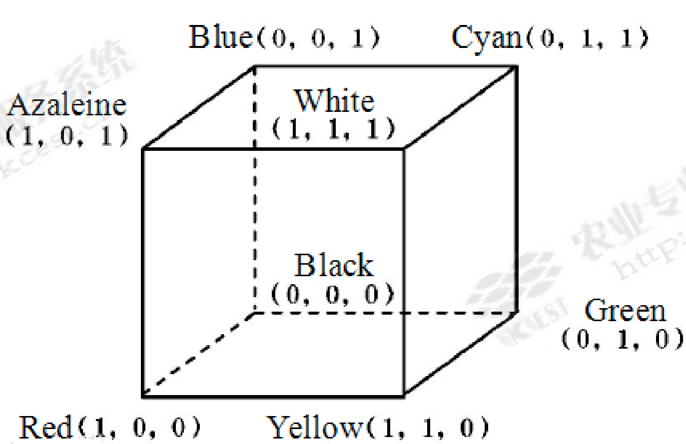

Fig. 5. The RGB Color Space.

In the RGB model, every pixel is composed of : red, blue and green(as shown in Figure.6.). It means that the RGB model has three pixel layers. The extraction of red feature on every pixel is achieved through the following formula:

$$V = 2R - B - G \qquad (1)$$

The value of "V" is bigger than 0 means red feature of the pixel is more pronounced, and the pixel can be regarded as a "red" one.

4. EXPERIMENT AND ANALYSIS

4.1 Apple Extraction Process Based on Matlab2017

The image acquisition system acquires the colour image and colour image is performed grayscale processing. Then the grayscale image is binarized — threshold segmentation method based on the grayscale, in which the threshold takes 0.65. 0.65 means that the values of every pixel are arranged from small to big, the first 65% of the pixel values are all judged to be "0"(black) and the remaining pixel values are judged to be "1"(white). After the binarization, image needs to be performed open operation and noise reduction processing (including erosion and expansion operation). The position determination image is obtained. The process is shown in Figure.7.

The biggest advantage of RGB color space is that it is intuitive and easy to understand. The image information obtained by the acquisition can be applied directly without color space conversion operation.

The binarization image processing algorithm based on MATLAB2017 is as follows:

```
src = imread('apple1.jpg');
figure,
subplot(2,2,1),imshow(src),title('Original')
thresh = graythresh(src);
bw = im2bw(src,0.65);
subplot(2,2,2),imshow(~bw),title('Binarization')
se = strel('disk',2);
openbw=imopen(bw,se);
subplot(2,2,3),imshow(~openbw),title('After open operation')
I=imread('apple1.jpg');
I=rgb2gray(I);
Ibw=im2bw(I);
[l,m]=bwlabel(~openbw,8);
status=regionprops(l,'BoundingBox');
subplot(2,2,4),imshow('apple1.jpg'),title('Position
determination')
```

```
for i=1:m
    rectangle('position',status(i).BoundingBox,'edgecolor','r');
end
hold
```

In order to ensure that the apples can be positioned more accurately, we tried another image processing method — the OTSU method(maximum variance between clusters). In Otsu's method, OTSU exhaustively searched for the threshold that minimizes the intra-class variance, defined as a weighted sum of variances of the two classes.

$$\sigma_{\omega}^{2}(t)=\omega_{1}(t)\sigma_{1}^{2}(t)+\omega_{2}(t)\sigma_{2}^{2}(t) \quad (2)$$

$$\sigma_{b}^{2}(t)=\sigma^{2}-\sigma_{\omega}^{2}(t)=\omega_{1}(t)\omega_{2}(t)\left[\mu_{1}(t)-\mu_{2}(t)\right]^{2} \quad (3)$$

In formulas (2) and (3), Weights ω_i are the probabilities of the two classes separated by a threshold t and σ_i^2 variances of these classes. Otsu shows that minimizing the intra-class variance is the same as maximizing inter-class variance. Formulas (3) is expressed in terms of class probabilities ω_i and class means μ_i which in turn can be updated iteratively. This idea yields an effective algorithm.

(a) (b) (c)

Fig. 6. The component diagram of R, G, B.

The algorithm based on MATLAB2017 is as follows:

```
function level = otsu(histogramCounts, total)
sum0 = 0;
w0 = 0;
maximum = 0.0;
total_value = sum((0:255).*histogramCounts');
for ii=1:256
   w0 = w0 + histogramCounts(ii);
   if (w0 == 0)
      continue;
   end
   w1 = total - w0;
   if (w1 == 0)
      break;
   end
   sum0 = sum0 +  (ii-1) * histogramCounts(ii);
   m0 = sum0 / w0;
   m1 = (total_value - sum0) / w1;
   icv = w0 * w1 * (m0 - m1) * (m0 - m1);
   if ( icv >= maximum )
      level = ii;
      maximum = icv;
   end
end
end.
```

As shown in the position determination image respectively, when the binarized image was positioned, the framed position contained the shadow. The image processed by the OTSU method was more accurate.

4.2 Design of the Shell

In order to ensure that the apples can enter the picking device smoothly, the size of the shell needs to have enough margin. The shape of the apple is similar to a sphere. Ten apples were measured randomly, and the diameters of the ten apples were 76, 78, 81, 72, 86, 79, 84, 75, 88 and 80mm respectively. The average value of the ten apples was 79.9mm, where the biggest apple is about 22% larger than the smallest one. According to the average diameter of 79.9mm, if the cross section of the shell is designed to be a square with the side length of 120mm, the shell is about 50% bigger than 79.9mm, which can make apples enter the picking device successfully.

5. CONCLUSION

From this paper, the picking device adopts a relatively simple structure and an effective cutting device. The apple picking device can meet the needs of robots picking apples and improve picking efficiency and quality.

After comparing the image recognition processing experiments, we found that the OTSU method is much more accurate than commonly used binarization image processing method. The OTSU method can greatly improve the accuracy of feature extraction and the processing on the shadow is more significant.

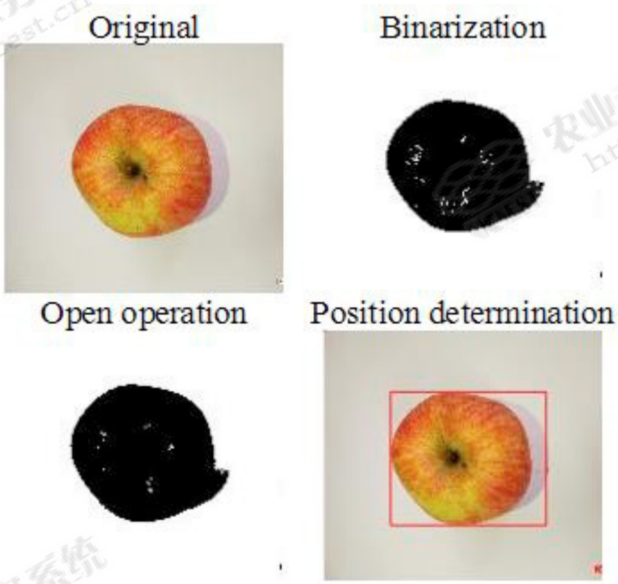

Fig. 7. The binarization Image processing.

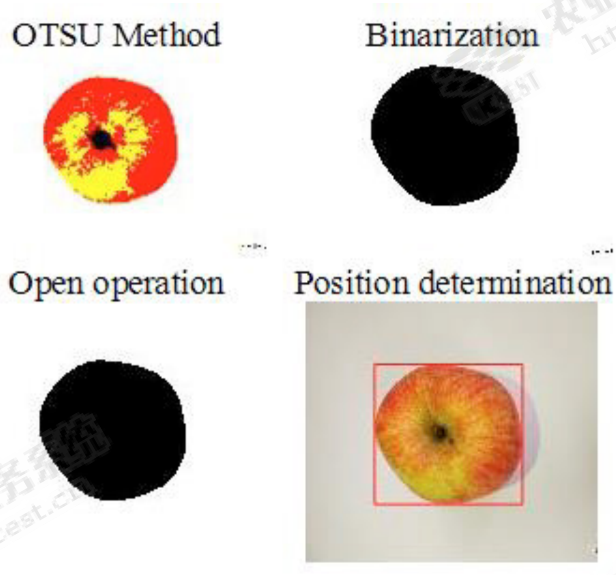

Fig. 8. The OTSU Image processing.

The current design of the shell with the side length of 120mm can ensure that the vast majority of apples enter the picking device successfully. In the subsequent design, we will consider to make the shell adjustable to adapt to different size and maturity of apples.

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