Research on Picking Identification and Positioning System Based on IOT

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Abstract—The key and necessary condition for accurate picking are to identify and locate the target fruit accurately. This paper focuses on the development of picking robot, mainly through two aspects: software and hardware. Moreover, it mainly consists of the binocular vision system and the camera calibration model. Based on these two core components, it can complete the function of identification and positioning. The results show that it can accurately locate the target location in the aspect of recognition function. What is more, its error is no more than 8mm, and its picking rate is over 96%. It shows high precision and efficiency, which plays a decisive role in the realization of picking automation.

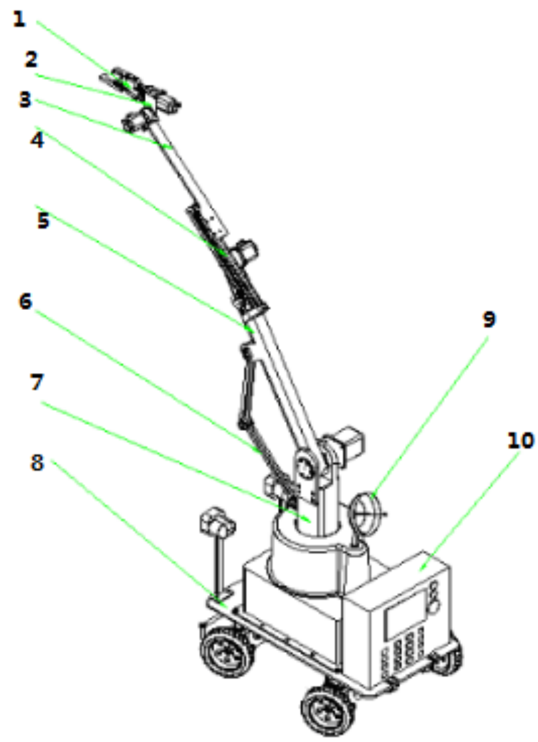
Keywords—picking robot; vision system; target fruit; positioning;IOT

1 Introduction

The rapid development of Intelligent Agriculture in China has benefited from the in-depth promotion of the block chain agricultural platform. It has brought a broad prospect for its development. Based on the latest agricultural production mode, agricultural robots will become the backbone of agricultural production in the future. Agricultural robots developed from the combination of automation and agricultural production technology bring new productivity and labor force to the agricultural production. Agricultural robots, including picking robots, play a decisive role in the fruit production industry. This research based on binocular vision system and camera calibration model, and developed a vision recognition system for the development of picking robots, able to complete the identification and positioning of the target fruit.

2 The overall design of the system

This research mainly focuses on developing the visual recognition system for picking robots. It chiefly provides intelligent service for picking fruits in agriculture. What is more, its essential function is to identify and pick fruits from trees. The work flow of the whole robot includes: The advanced identification and location of targets, which mainly rely on CCD cameras. The system will process the captured images and locate the objects according to the information processed, and make sure the specific coordinates of the objects can be quantified. After receiving the coordinate information of the object, the control system will control the motor to prepare for picking activities. Later on, the target is picked up under the command of the system. The hardware part of the whole system (see Figure 1) mainly includes: the end-effector, the CCD camera, the main arm, the servo motor, the main control part, the sensor module, the vehicle acoustic carrier, the large arm auxiliary component, the large arm component, the small arm component and so on.



1. The end-effector 2. The CCD camera 3. The small arm component 4. The servo motor 5. The large arm component 6. The larger arm auxiliary component 7.the main arm8. The vehicle acoustic carrier 9. The sensor module 10. The main control part

Fig. 1. The overall structure of picking positioning system

2.1 System hardware planning

The whole picking robot consists of two parts (see Figure 2), including a platform with mechanical components, and the most significant control system. In the system hardware, the acquisition of objects is accomplished through visual sensors. After that, image analysis and processing the coordinate information of the acquired objects, which through the professional software that collocated in the system. In this way, to complete the identification and positioning work, which lays the foundation for picking.

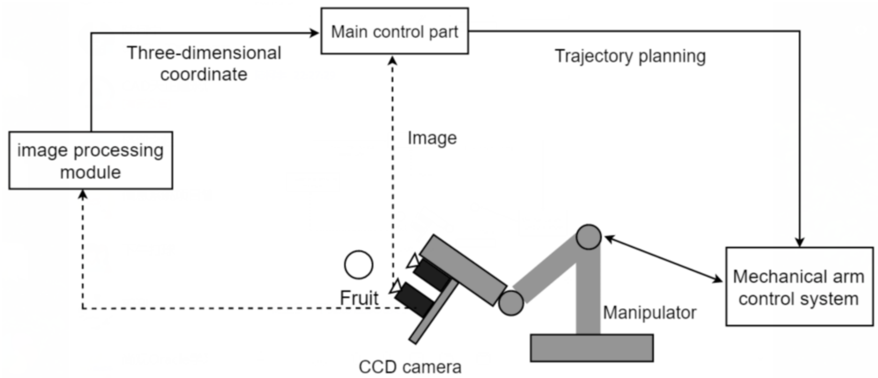


Fig. 2. The schematic diagram of the fruit recognition system for the target of the picking robot

In the picking robot system, the end-effector is responsible for picking. It completes the picking of objects by working with the manipulator control system. The whole picking process is combined with the main controller and the servo drive. In this study, the core processor type of hardware accessories (see Figure 3) is DSP. It includes six parts: vision system, mechanical arm, end-effector, a host computer and mobile device.

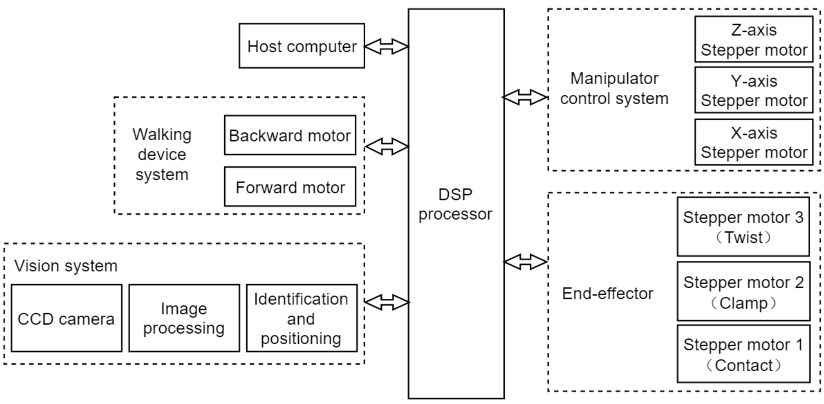


Fig. 3. The circuit control frame diagram of target fruit recognition system

2.2 System software design

In this study, the control of picking robot occurred by remote control. The development of control software completed in the QT environment. The software can assist the operator to remote control the robot to pick the target. Detailed reference related to the development and use of software refer to Figure 4 and Figure 5.

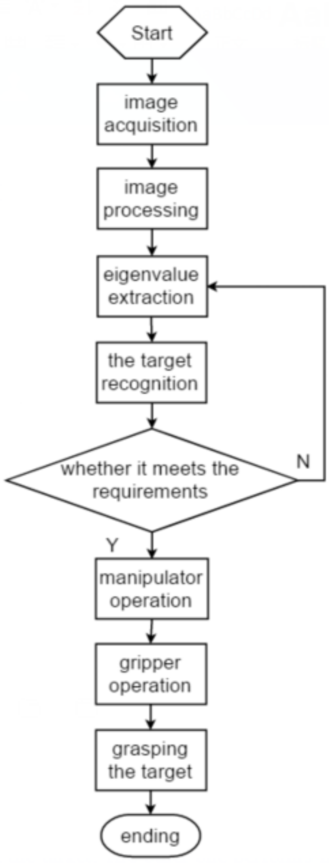


Fig. 4. The schematic diagram of the software flow of the intelligent picking robot system

3 Machine vision system design

The identification of objects and the determination of their three-dimensional coordinates together constitute the visual system elements of the picking system. In this study, the matching of visual sensors is achieved through the MV-EM series small gigabit CCD camera of Micro-vision Digital Image Technology Co. Ltd. What is more, And it used professional software to process image information. The image of the specific hardware device refers to Figure 6.

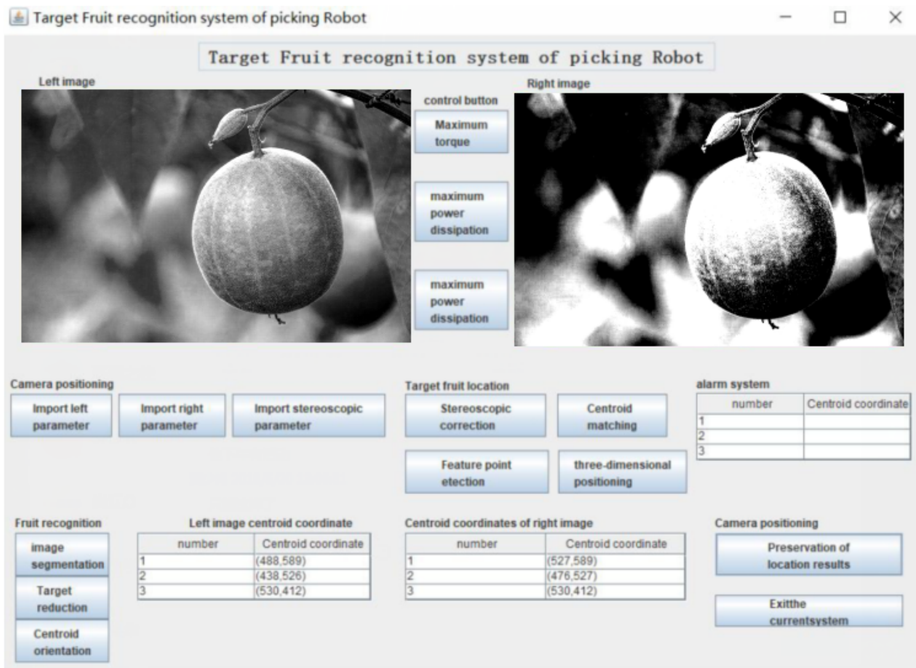


Fig. 5. The master computer interface diagram

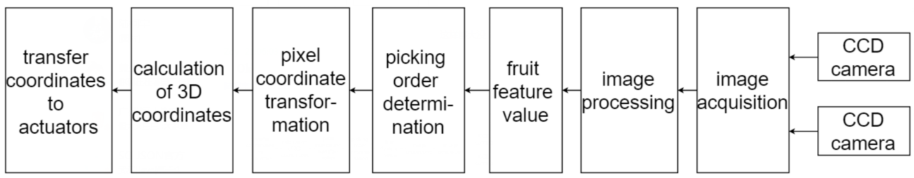


Fig. 6. The work frame diagram of visual system for picking robot

The most crucial part of the whole recognition system is the vision system, which includes CCD camera and image processing. The former module is responsible for the image acquisition of the target. The other one performs information processing on the acquired image. It converts image information into positioning data information, that is, three-dimensional coordinate information. Therefore, it helps the next step of picking operation.

4 Camera calibration model and identification and positioning of target fruits

4.1 Camera calibration model

Two-dimensional projection of objects and their surrounding 3D scenes is carried out by using image transformation. This is the imaging principle of the camera. Usually, this model consists of two components, which are the linear model and the non-linear model. The most typical linear model is pinhole imaging model. What is more, the imaging model used in this study is pinhole imaging model. The specific calculation of different spatial fields through projection to plane points and corresponding three-dimensional coordinates is made of reference to Figure 7. The way of realization is as follows:

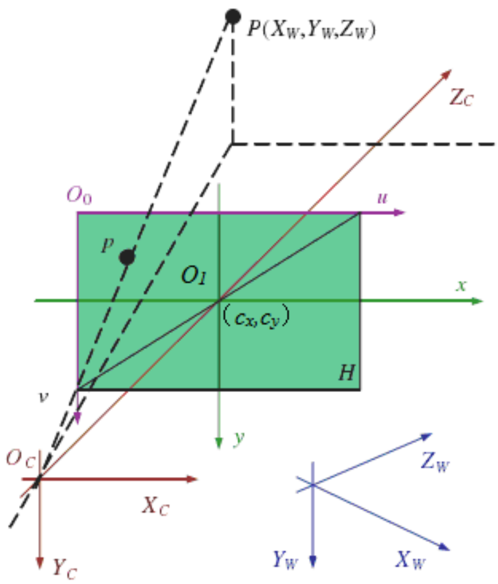


Fig. 7. The imaging model of 3D image

1. First of all, the determination of the camera coordinate system $O_C X_C Y_C Z_C$;
2. Complete the creation of reference world coordinate system （X_W,Y_W,Z_W）；
3. Construction and determination of imaging coordinate system（x,y,z）；
4. u-o-v completes the building of the image coordinate system, mainly based on pixels in the image.

The image coordinates are transformed into pixel coordinates by homogeneous coordinate transformation(u,v). The implementation method is:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{d_u} & s & u_0 \\ 0 & \frac{1}{d_v} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \tag{1}$$

u_0 and v_0 are used as the central coordinates of the image. However, d_u and d_v represent the objective physical size of the pixels in different units, length of the projection on the X and Y axes respectively. There is a dip angle between the optical axis and the coordinate system. In this paper, use the slope factor s to calculate this dip angle. The following formula can be used to complete the transformation from image coordinates to pixel coordinates.

$$\begin{cases} u - u_0 = fs_x x / z = f_x x / z \\ v - v_0 = fs_y y / z = f_y y / z \end{cases} \tag{2}$$

In this formula, $f_x = fs_x$, $f_y = fs_y$ represent the equivalent focal length of different pixels on the X and Y axes. Through the linear model calculation method, the final homogeneous coordinate transformation formula is:

$$Z_C \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x & 0 \\ 0 & f_y & c_y & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & t \\ O^T & 1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} \tag{3}$$

$$R = \begin{bmatrix} r_1 & r_2 & r_3 \end{bmatrix} \begin{bmatrix} \cos\psi\cos\theta & \cos\psi\sin\theta\sin\varphi & \cos\psi\sin\theta\cos\varphi \\ \sin\psi\cos\theta & \sin\psi\sin\theta\sin\varphi & \sin\psi\sin\theta\cos\varphi \\ -\sin\theta & \cos\theta\sin\varphi & \cos\theta\cos\varphi \end{bmatrix} \tag{4}$$

$$T = \left(t_x, t_y, t_z\right)^T \tag{5}$$

In this formula, ψ represents the inclination angle; θ represents the pitch angle; φ represents the rotation angle; the vector R is an orthogonal rotation matrix. The coordinates of the origin of the world coordinate in the camera coordinate system represented by vector T=$[t_x,t_y,t_z]^T$.

4.2 identification and positioning of target fruits

Most animals have two eyes, and there is a distance between them. This will cause differences in the images observed by the two eyes. This difference can be used to locate the target. The design of binocular vision system is based on this principle to complete the identification and positioning of objects. First of all, a dual CCD camera is used to photograph the target simultaneously. After that, the system for information retrieval and data model calculation is based on the two different images that have filmed at the same time. Finally, the system constructs the 3D model of the object and calculates its three-dimensional information. The specific way of accomplishment shown in Figure 8.

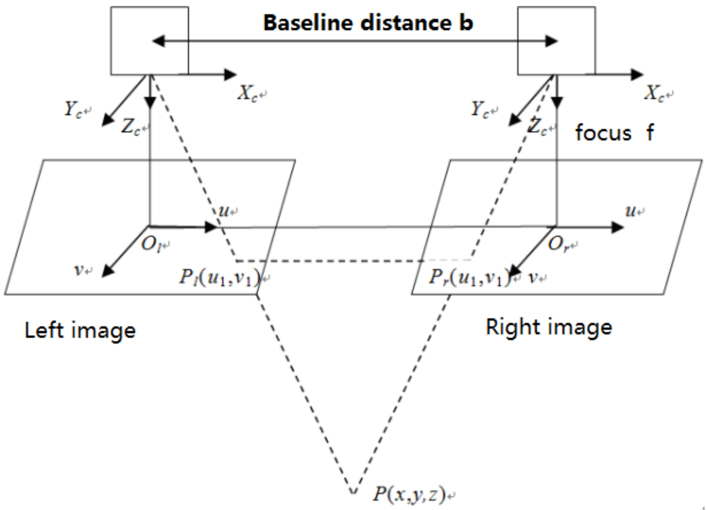


Fig. 8. Fig.8 The schematic diagram of the principle of binocular vision positioning

The two cameras used in the system are identical in type, shooting parameters and so on. They shooting objects at the same time, respectively. Therefore, it can get the coordinates of the target information as $pl(ul,ul)$, $pr(ur,ur)$. Because different CCD cameras installed at the same height, the target P can form $Yl=Yr=Y$ in different imaging systems. It is known that the fixed distance between these different cameras is d and the focal length is f, according to the Pythagorean theorem:

$$\begin{cases} X_l = f\dfrac{x}{z} \\ X_r = f\dfrac{(x-b)}{z} \\ Y = f\dfrac{y}{z} \end{cases} \tag{6}$$

After conversion, the three-dimensional coordinates of P can be calculated:

$$\begin{cases} x = \dfrac{u_l}{u_l - u_r} d \\ y = \dfrac{v_l}{u_l - u_r} d \\ z = \dfrac{f}{u_l - u_r} d \end{cases} \tag{7}$$

In this camera calibration, d = 56mm, f = 1268 pixels, and bring into (7), that is, the three-dimensional coordinates of P.

5 Analysis of experimental results

In the field test of the developed system, the primary test index is the feasibility level and the accuracy level of the picking robot, the experimental site is an apple plantation, and the test time is2017.11.18 − 16: 00. Before starting the test, light treatment for apples with more obscured light, and then conduct two experiments which are toward the light and against the light. The specific records of the experimental data are shown in Table 1 and Table 2.

Table 1. The localization test results of target fruit

NO	**elemental area/Original**	**Fruit radius （mm）**		**distance （mm）**	
		Picking robot	***artificial***	***Picking robot***	***artificial***
1	8185/0.82	71	76	745	740
2	10682/0.75	66	69	813	819
3	11956/0.72	68	74	781	787
4	12519/0.87	73	71	760	768
5	13843/0.91	82	85	829	823
6	21268/0.73	90	96	832	835
7	25447/0.88	86	90	832	826
8	30412/0.80	75	80	746	749

Table 2. The picking experimental results

	environmental aspect	
	phototropic	***in shadow***
Number of ripe fruits /each	183	178
Number of successful picking/each	162	165
Recognition success rate /%	92.3	89.5
Localization success rate /%	90.6	88.7
Successful picking rate /%	88.5	86.43

The experimental data shows that the picking robot has excellent picking effect in both two experimental environments. The recognition accuracy is high, and the positioning is accurate. In all positioning data, the error is no more than 8mm, which fully accords with the requirement of fruit picking for robots. In the aspect of recognition function, it can realize accurate positioning of the target. What is more, its error is no more than 8mm, and its picking rate exceeds 96%. In other words, it shows high precision and efficiency. And it plays a decisive role in the realization of picking automation.

6 Conclusion

This paper focused on the development of the picking robot, mainly through the two aspects of software and hardware to complete the research. It primarily consists of the binocular vision system and camera calibration model. Based on these two core components, achieve the function of identification and positioning. The research results show that: In the aspect of recognition function, it can realize accurate positioning of the target. What is more, its error is no more than 8mm, and its picking rate exceeds 96%. In other words, it shows high precision and efficiency. And it plays a decisive role in the realization of picking automation.

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