Computer Life (CPL) ISSN: 1819-4818
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# Design of Intelligent Fruit Picking Robot Based on OpenCV

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*Abstract: With the expansion of fruit planting area and the increase of labor costs, how to collect fruit more efficiently and quickly is becoming more and more important problem. This paper introduces a fully automatic picking system that mainly realizes apple recognition, reaching the target location, and apple picking these functions. No manual intervention is required throughout the process. First, we capture the images by the camera, and then we use OpenCV to determine the location and distance of the apple. Then, the Arduino system is used to control the robot arm to move to the target position. Finally, the apple is picked up by the negative pressure collecting device. The entire system consists of three parts: OpenCV based image processing, arduino-based master control system and overall mechanical structure, designed to complete a smart picking system, aimed to complete a set of intelligent picking systems.*
*Keywords: Picking robot, Image processing, Arduino control system, Negative pressure collecting device.*

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## 1. PREFACE

In order to solve the problem of low fruit picking efficiency and high labor cost, domestic and foreign scholars have conducted some research. Such as MAGLIAUFO (Apple Picking Robot), CIRUS (Citrus Picking Robot), AUROB0T (Tomato Picking Robot) [1].

Among them, by modifying the SCORBOT-ER industrial robot, Kondo et al invented a high-degree-of-frees picking robot that can find mature tomatoes through a visual monitoring system and can grasp fruits with a robotic arm. [2] In addition, the cucumber picking robot developed by the IMAG Institute of the Netherlands is mainly composed of an electric knife and a driver, and can disinfect the cut surface. [3] In this paper, the automatic picking of fruits is accomplished mainly through the combination of image processing part, mechanical arm and negative pressure collecting part. The design proposed in this paper is mainly to achieve automatic fruit picking by combining the image processing part, the mechanical arm and the negative pressure collecting part.

## 2. OVERALL STRUCTURAL DESIGN

In order to meet the requirements of control and automation required by the picking robot, the design uses the Arduino microcontroller as the main control circuit, the Raspberry Pi as the image processor, and the structure of the robot arm is controlled by a separate robot arm controller. The detail of these parts:

1. The Raspberry Pi image processing unit is mainly responsible for real-time image acquisition and processing. It recognizes apples by color space change, morphological processing and Hough circle detection of the original images, and outputs the relative coordinates of the apples to the Arduino control unit.

2. The Arduino Control Unit is mainly responsible for controlling the operation of the whole system. After obtaining the coordinate data of the Raspberry Pi, the Arduino control unit can analyze the coordinate data and transmit the analyzed coordinates to the robot control unit. Through the Arduino control unit, the entire picking process can be controlled by means of a serial port or a button.

3. The Robot Arm Controller Unit is mainly responsible for controlling the robot arm to reach the specified coordinate position, so that the collector can reach the apple position.

The core control unit of the arm system contains PCM code modulation function, which can control the three-axis servo of the arm. The robot can be controlled to reach the designated position and the apple can be picked, so that the whole system can operate normally and effectively.

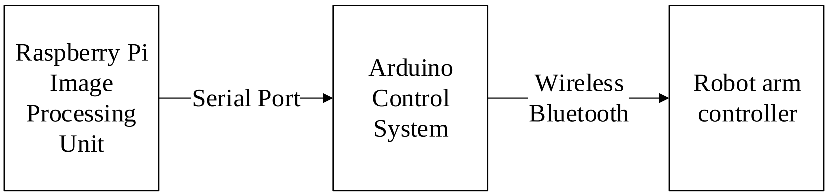


Fig 1 Overall block diagram.

## 3. HARDWARE DESIGN

### 3.1 Raspberry Pi Image Processing Unit

The Raspberry Pi image processing unit internally runs a Linux-based Raspberry system. Its USB interface is connected to a 1080P HD camera and transmits image data to the Raspberry Pi image processing unit. The Raspberry Pi's built-in I2C interface makes it easy to connect to ultrasonic range detectors. During the running process, the camera data and the ultrasonic detector`s distance data are mixed together, and the apple coordinates are acquired through image processing and data processing integration. Apple's three-dimensional coordinates are finally converted in a format and sent to the Arduino control module via serial communication.

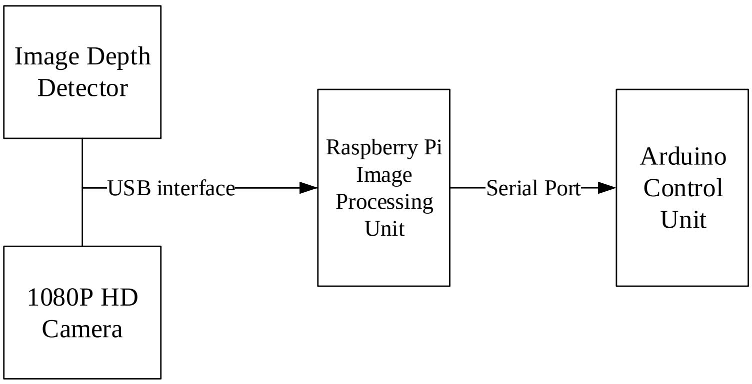


Fig. 2 Flow chart of apple recognition process

### 3.2 Robot arm controller

The arm controller controls the steering gear angle by the PCM signal. The position of the end of the arm can be controlled by controlling the motor to rotate to a specified angle using PCM signals of different frequencies. In order to effectively improve the calculation efficiency and make the precision not more than $\sqrt{2}/2$ pulse., the control of the arm adopts the three-dimensional linear interpolation algorithm [4]. Through the three-dimensional linear interpolation algorithm, the robot arm can be in higher efficiency and higher precision in an effective time.

The robot controller also controls the operation of the negative press. The negative pressure machine uses a 24V powered electric air compressor, which is controlled by relay isolation. The electric air compression engine can generate 85Kpa negative pressure, The suction port is connected to the hose, and the electric air compression engine is activated and sucked when it reaches the apple position.

### 3.3 Robotic arm platform

The mechanical arm platform mainly includes a chassis, a servo processor, a vacuum device, a supporting mechanism, a camera, an image processor, a support frame and a net pocket;

1. The support mechanism is installed between the chassis and the support housing, which is responsible for supporting the entire mechanical structure.
2. The negative pressure nozzle and the camera are respectively located in front of and above the support housing
3. The inner hose of the fruit picking device is connected to the lower end of the fruit picking device, and the lower end of the fruit picking device has an electric air compression engine. There is also an ultrasonic detector device under the fruit picker to detect the distance between the fruit and the fruit picker.

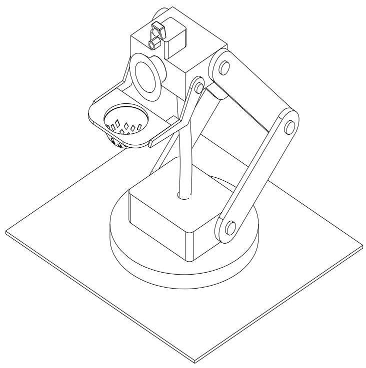

Fig. 3 Robotic arm platform

When the mechanical arm reaches the designated position, the robot arm is first moved to the target position by the detected depth, then the electric air compression engine is turned on to adsorb the fruit. Finally, after the collection is completed, the negative pressure machine is turned off and the fruit falls into the net pocket to complete the picking.

## 4. IMAGE PROCESSING SOLUTION

### 4.1 Results of a single apple experiment

There are three main problems to be solved in image processing: apple recognition, judgment of apple maturity and distance positioning between apple and picking device. This paper divides the apple recognition part into two cases with overlapping and non-overlapping regions. For the case of no overlapping area, firstly, we will change the original image of the acquired color space, increase the contrast of the red component, and then identify the apple by the morphological processing and the Hough circle detection method. For the case of overlapping regions, apples can be identified by curve fitting in combination with the Hough circle detection method. In the judgment of apple maturity, this paper determines the mature fruit by comparing the color pixel values.

Figure 4 shows the specific process of overlapping apple recognition.

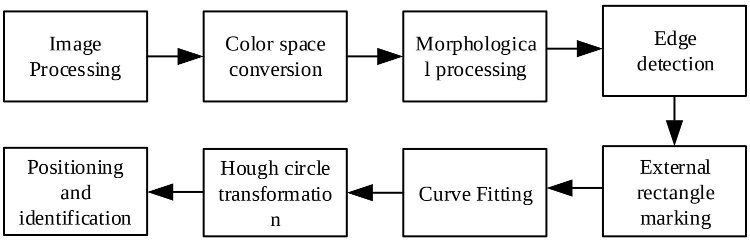


Fig. 4 Flow chart of apple recognition process

Specifically, it mainly includes:

1. Convert the RGB color space to the YCrCb[5] color space and separate the Cb channel as the basis for image processing. Mainly used to reduce the influence of factors such as lighting in the external environment on the graphics.
2. The minimum circumscribed rectangle marking method [6] ,using a minimum rectangular box to segment the target to be detected;
3. Curvature fitting using the curvature feature of the contour
4. Recognition of Apple by Gradient Hough Circle Transform Algorithm
5. Filter the target through the color threshold and transfer the center position coordinates of its image to the Arduino control element.

## 5. IMAGE DEPTH RANGING SCHEME

Since the image processing uses a monocular camera, the image depth cannot be recognized. We need to find a way to capture image depth data.

At this stage, there are relatively many ranging methods, including nuclear radiation ranging, microwave ranging, laser ranging, binocular vision ranging and ultrasonic ranging. Ultrasonic has good directionality, anti-photomagnetic interference capability, and is not affected by air visibility. Therefore, it has been widely applied and promoted in various fields such as medical flaw detection, robot visual recognition and surveying. Therefore, we use ultrasonic distance detector to collect image depth information.

The KS103 ultrasonic module has good reliability and high precision. It is widely used in robot structures with an accuracy of 1-3mm to meet design requirements, so we installed the module directly below the camera. With the help of the ultrasonic distance detector, specific depth data of the identified image can be obtained, thereby obtaining the three-dimensional coordinate data of the target. Since the ultrasonic wave has a detection range problem, when the camera recognizes that the apple is in the visible range, it first determines whether the apple position is located in the ultrasonic sensing area, and if it is located in the ultrasonic sensing area, activates the ultrasonic wave to perform the distance detection. The detected distance data is combined with the two-dimensional data collected by the camera to obtain the three-dimensional coordinates of the apple.

## 6. NEGATIVE PRESSURE COLLECTION MECHANICAL STRUCTURE

The negative pressure picking system uses the vacuum of the electric air compression engine to detach the apple from the fruit tree. The internal structure consists of a electric air compression engine and a hose. The electric air compression engine is integrated into the arm unit and connected to the fruit basket and the fruiting tube through a conduit. After the robotic arm reaches the apple position, the vacuum pump will start and suck the fruit into the fruiting catheter, and the apple will be sent through the catheter into the fruiting basket. A pressure sensor is installed on the vacuum pipe. If a certain pressure is detected, the apple has been successfully sucked, and then the apple will continue to be sucked until the pressure is restored to atmospheric pressure, and the vacuum system is closed. For different sizes of fruit, a negative pressure picking system can be used to ensure effective harvesting of apples, increase speed, and reduce skin damage to apples.

The switch of the vacuum device is controlled by the Arduino control system through the serial port. When the Arduino processor detects that the mechanical arm reaches the target specified position, it sends a signal to turn on the engine. When the signal sent by the end of the pipette pressure sensor is detected, the arm begins to carry the fruit, and then the robot controller sends a signal to close the negative pressure to complete the acquisition process.

## 7. OVERALL IMPLEMENTATION SET

Using all of the units above the passage, we finally created the whole system to pick up the fruit. After the initialization of each component is completed, the image captured by the camera is sent to the Raspberry Pi, the target two-dimensional coordinates are returned by image processing and transmitted to the Arduino processor to control the rotation of the robotic steering gear. After reaching the specified position, the ultrasonic detection module is turned on to measure the picking end to the target distance, and then the electric air compression engine is started. After completing a series of operations, the vacuum is closed and the fruit is rolled into the collection basket through a plastic hose.

The Arduino master control system is mainly responsible for data conversion and transmission, servo control, and the number of records collected, picking speed and so on during the picking process. Its core function is to convert the returning coordinate parameters after image processing and the distance parameter returned by ultrasonic ranging into the angle and several degrees of rotation of the steering wheel of the mechanical arm. The parameters for recording the picking process are mainly for the convenience of the user to understand in real time and future improvement work.

In the end, the Picking robot based on OpenCV has achieved high requirements in terms of accuracy and efficiency, which can meet the needs of actual fruit picking.

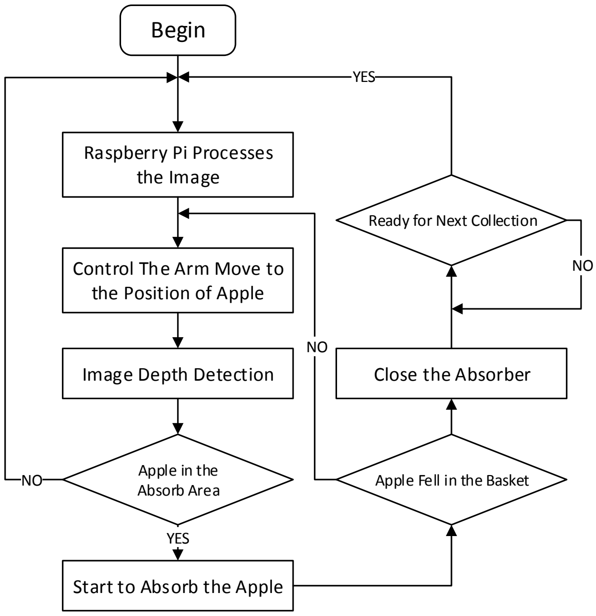


Fig. 5 Flow chart of action plan

## ACKNOWLEDGEMENTS

I would like to thank the University Students Innovation and Entrepreneurship Project Team for their financial support for the research and innovation project “201810058019 OpenCV-based automatic fruit picking robot”.

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