Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Design and research on the End Actuator of Tomato Picking Robot

To cite this article: Chen Huangfei and Fang zhuangying 2019 *J. Phys.: Conf. Ser.* **1314** 012112

IOP Conf. Series: Journal of Physics: Conf. Series **1314** (2019) 012112 doi:10.1088/1742-6596/1314/1/012112

Design and research on the End Actuator of Tomato Picking Robot

Chen Huangfei, Fang zhuangying

Huali College, Guangdong University of Technology, Zengcheng, Guangdong, China

531028136@qq.com

Abstract. Fruit and vegetable harvesting machine can achieve timely harvesting of fruits, improve production efficiency and product quality, and also improve labor conditions. It can replace manual completion of various complex and dangerous work, improve work efficiency and reduce labor costs. In this paper, the end-effector of Tomato Picking Robot is studied, the development status of the end-effector at home and abroad is briefly described, the design structure and principle of the end-effector of various tomato picking robots are analyzed and compared, and the problems and key technologies of the end-effector design of Tomato Picking Robot are expounded. which provides a powerful reference for further design and research.

1. Introduction

With the development of modern intelligent technology, the application of various intelligent robots has penetrated into all areas of our life. At present, the technology of picking robots has developed rapidly at home and abroad. For example, Japan, the United States, the Netherlands and other developed countries have developed a variety of fruit and vegetable picking robots and their end effectors successively. Japan's robotic arm designed for Tomato Picking has seven degrees of freedom. It takes pictures through cameras, recognizes fruits through sensors, and locates them through binocular vision. Spanish-designed manipulator can judge the maturity of Citrus according to its size, shape and color, and finally determine whether it meets the picking conditions, and so on.

In recent years, domestic research on various kinds of fruit and vegetable picking robots has also achieved certain results. Eggplant, strawberry, tomato, apple and other picking robots and their end effectors have been developed successively. The tree cone picking robot of Northeast Forestry University is driven by hydraulic system and controlled by single chip computer. The robot picks fruit by holding the root of the branch to the end by the end-effector. The picking efficiency is high. Shenyang Institute of Automation has developed a tomato picking device. Robot-assembled manipulator uses a four-fingered mechanism, which can hold fruit stably and absorb fruit through sucker.

Although the above end effectors can achieve the task of efficient harvesting, they can also be improved in many aspects, such as large size, inconvenient movement, heavy weight, inadequate lifting height, or tree damage in the process of harvesting. Therefore, the technical level of end-effector needs to be improved. This paper takes Tomato Picking Robot as an example to design and compare its end effector.

2. General structure and principle

The end effector of the picking robot is a device installed in the front of the manipulator, which directly contacts the picking target to realize the movement and additional functions required for fruit and vegetable picking. It is the key part of the picking robot to achieve fruit and vegetable picking. Tomato is the main picking object of the end-effector of the picking robot in this paper. The hardware of the end-effector is mainly composed of the executive system, the perception system, the control system and the power supply system. The main structure of the end-effector is shown in Figure 1.

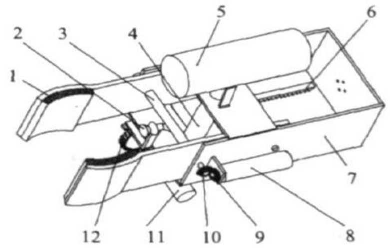

Figure 1. The main structure of the end-effector of Tomato Picking Robot [5]
1. Finger 2. Vacuum corrugated sucker 3. Bidirectional screw 4, 8, 11. DC servo motor 5. Laser focusing lens 6. Rack 7. Shell 9, 10. Bevel gear 12. Gear

The position, distance and shape of the object are acquired by the proximity sensor in the sensing system, and the vacuum sucker is controlled by the information fusion of multi-sensors. When the fruit is absorbed, the fruit is pulled back and separated from the fruit bundle. When the finger is closed, the gripping force and sliding information are feedback by the force sensor to control the finger to grip reliably but not to the fruit. The laser focusing lens rotates, locates on the stem and cuts off the stem by laser beam; the manipulator drives the end effector to put the fruit into the storage box, thus completing tomato picking.

3. Execution System

In order to achieve the goal of harvesting fruits, the end effector of harvesting robot must achieve two key actions: harvesting and separating, that is, firstly, harvesting fruits by non-clamping or non-clamping, and then separating fruits from stalks by cutting, twisting and other different methods.

This design chooses vacuum sucker suction, finger clamping and laser cutting to form a complete execution system. Targets are absorbed by suckers to increase the success rate of finger clamping and avoid finger damage to other fruits during the clamping process. The end effector of tomato picking robot developed by Japan and the United States [1-2-3] also uses such a sucker mechanism to successfully absorb the target fruit and pull it away from the fruit bundle.

3.1. Vacuum chuck

The main function of vacuum sucker device is to pull the target fruit away from the fruit, so as to increase the success rate of finger clamping and avoid finger damage to other fruits during the clamping process, including vacuum system and sucker feeding mechanism. Vacuum system controls the suction cup to absorb fruit steadily and reliably. It is a vacuum generating equipment consisting of a small compressed gas tank as the gas source and a small vacuum generator. The vacuum ripple suction cup with good cushioning performance adapted to curved surface and uneven workpiece is adopted, and the vacuum system of the end-effector of Tomato Picking Robot is composed of vacuum hoses, joints and other accessories. In the sucker feeding mechanism, the vacuum corrugated sucker is fixed at the front end of the rack, driven by a miniature DC servo motor, and driven by the rack and gear drive to move the sucker forward and backward, and cooperated with the vacuum system to complete the task of sucking and pulling fruit.

3.2. Fnger clamping mechanism

In order to ensure the reliability and universality of the clamping structure, and not to complicate the structure, the two-finger clamping method is chosen in the design. The finger width is 50mm. In order to enhance the reliability of the clamping, the finger surface is designed as a circular arc, and the inner finger is pasted with rubber 5.5mm thick to increase the buffer and reduce the damage of the clamping to the fruit. The finger clamping mechanism is driven by a DC servo motor. Through the transmission of a pair of bevel gears, the two-way screw with two threads of left and right rotation is driven to rotate, so that the two fingers of the helical pair formed with the two fingers produce parallel relative motion, thus closing or loosening. A few end-effectors adopt flexible finger structure, such as the end-effector of tomato picking robot developed by Monta, Japan, which has four flexible fingers, each finger is fixed on the nylon support board by four connected nylon hoses, and one cable is fixed on the finger end through the hose. When tension is applied to the cable, the fingers bend to grasp the fruit, as shown in Figure 2. The end-effector of tomato picking robot developed by Peter P. Ling in the United States replaced nylon with a harder ABS plastic pipe to reduce the lateral motion during clamping, as shown in Figure 3.

Figure 2. Tomato picking end effector [2]

Figure 3. Tomato picking end effector [3]

3.3. Laser Cutting Device for Fruit Stem

At present, scissors are usually used to cut or twist, but scissors need corresponding mechanism and larger driving force, which will increase the size and quality of the end-effector of picking robot. For example, the Tomato Picking end-effector developed in Japan cuts the stem directly, the fruit falls to the ground or falls into the pre-placed fruit box, and the end-effector itself can not achieve fruit recovery. It is necessary to control the clamping force accurately because the method of twisting and breaking the stalk requires a greater clamping force on the fruit, otherwise it is easy to cause fruit rupture and damage.

In order to solve the problem of separating fruit, a laser cutting device for fruit stalk is designed, which can cut fruit stalk conveniently by non-contact laser, and greatly reduces the complexity of robot end-effector and the requirement of clamping force control accuracy. The laser cutting device of fruit stalk consists of a laser generating control unit and a focus cutting unit of fruit stalk. During the operation, the binocular vision system fixed on the manipulator and the distance sensor on the end effector cooperate to precisely locate the fruit stalk; the focus lens is rotated by DC servo motor to align the lens with the fruit stalk; the laser is opened by solenoid valve, and the laser beam is focused on the fruit stalk (the focal length is 50 mm) and cut off. The tilt angle of the focusing lens can be adjusted to meet the pedicel length requirement of different varieties of fruits.

4. Perception System

In order to reduce the damage to fruits during harvesting and complete the harvesting action accurately, potentiometers, limit switches and multi-sensor are added to the end effector to realize the detection of sensing ability. It includes servo motor encoder, long distance and short distance sensor, proximity sensor, finger force sensor, wrist force sensor and pressure sensor distributed in each part of the end-effector to fully sense the internal and external information of the end-effector. The internal sensation includes the position and velocity of vacuum sucker, finger and laser focusing lens, the absorption and pulling state of vacuum ripple sucker on fruit, and the external information includes the sense of distance, proximity and force of operation target and environment.

(1) Distance and proximity sensors: a distance sensor is installed in the middle to detect the distance between objects in the range of 20-150 cm; a proximity sensor is installed at the front of two

fingers to detect the distance between objects in the range of 10-60 cm; and a proximity sensor is installed at the front of two fingers to sense the proximity of objects in the range of 10 cm. The information obtained by the above 1 remote sensor, 2 close sensors and 2 close sensors are fused to assist the picking robot and its end effector in finding targets, locating space, measuring the surface shape of fruits, determining the grabbing posture and action, and avoiding the collision of fingers with fruits.

(2) Three-dimensional finger force sensor: three-dimensional finger force sensor is installed on the inner surface of the two fingers of the end-effector, which can simultaneously detect three-dimensional force information (Fx, Fy, Fz). Six-dimensional wrist force/moment sensor is installed at the joint of the end-effector and the wrist of the manipulator. It can simultaneously detect all the force and moment information in three-dimensional space (Fx, Fy, Fz, Mx, My, Mz).

A mechanical contact sensor is installed at the front end of the sucker; it is used to detect the distance between the end-effector and the object; a small camera is installed on the end-effector to form a visual servo mode of "eyes on hands" as its visual system; and a potentiometer is installed to detect displacement. It is used to detect the displacement or rotation angle of the actuator, and a limit switch is installed to prevent the actuator from rushing out of the journey, causing unnecessary damage or injury to the end actuator, plant and operator. The end effector of tomato picking robot developed in Japan [1,4] has also been designed.

5. Control system

In order to use the portable computer + multi-axis motion control card as the upper control unit, the industrial control computer of open control system and desktop computer are more suitable for the control of mobile picking robot and end-effector than the portable computer, which occupies less space, has lighter weight and does not need AC power supply. The communication between the portable computer and the multi-axis motion control card is carried out by USB, which facilitates connection and disconnection; the multi-axis motion control card has built-in DSP digital signal processor and constitutes a master-slave dual-CPU control mode with the CPU of the portable computer. The CPU of the portable computer is convenient for programming and real-time monitoring, and the multi-axis motion control card can be disconnected from the portable computer as an independent motion controller. The operation makes the work of the picking robot and the end effector simpler and more flexible.

All sensor signals of the end-effector are converted into multi-axis motion control card by A/D conversion, and the control signal is output through I/O port of the multi-axis motion control card to form a feedback control system. The output control signal enlarges the signal of the driver, controls the position and speed of the motor, and realizes the precise control of the force and movement of the finger clamping mechanism and the vacuum sucker mechanism. At the same time, the vacuum generator is controlled by the solenoid valve, the optical fiber coupled semiconductor laser is controlled by the relay, and the fruit is picked according to certain sequence.

6. Existing problems

1) poor compliance: picking manipulator is the executing mechanism of fruitful vegetable picking. It is necessary to select appropriate flexible materials and flexible technology to ensure that the peel is not destroyed during picking. At present, the design of end-effector is mostly rigid structure, lack of flexibility, lack of force sense, slip sense and other information perception ability, and easy to damage fruit; very few are flexible finger mechanisms, but the applicability is insufficient. When there are obstacles such as branches and leaves, flexible finger will bend, resulting in the failure of fruit grabbing. So flexible technology is one of the key technologies.

2) The ability of intelligent recognition is poor. Because of the obstruction and obstruction of branches and leaves, the size difference of fruits and pedicels, the collision and obstruction of fruits and the errors of visual system, there are often deviations between the posture of end effectors and fruits during harvesting, and the poor adaptability to complex unstructured environment. From the

whole process of intelligent recognition, it includes camera technology, photoelectric conversion technology, image information processing technology, intelligent judgment technology and other comprehensive technologies [7].

In the process of fruit harvesting or target acquisition, in order to realize intelligence and automation, it is necessary to realize intelligent object recognition. In order to realize intelligent recognition, image acquisition is the first step. Image acquisition is very important, because it is directly related to the results of subsequent discrimination, so image acquisition needs to adjust the focal length reasonably according to the working distance in order to get the best picture. Nowadays, image recognition technology has the disadvantage of poor adaptive ability. If the collected image is distorted and incomplete or disturbed by strong noise, it can not get ideal decision results. In the practical application of intelligent recognition technology, there are often many unfavorable factors. For example, in the picking process, the rapid movement of the manipulator will affect the shooting light, causing errors [8.9]; Due to the different angles of shooting, the fruit can not be recognized and incomplete recognition due to occlusion and other factors; too strong or too weak light caused by weather factors will lead to data extraction errors, resulting in improper judgment results.These disadvantageous factors must be avoided as far as possible, which requires follow-up digital image processing technology, information extraction technology and discrimination technology to be more intelligent, which depends on the development and progress of artificial intelligence, systems and other disciplines.

3) poor universality. Because the shape and characteristics of different fruits are different, the sensing system of the end effector and the clamping force of the recognition system are also different. Whether or not the target will be broken depends on the clamping force, and the optimal value of the clamping force is the maximum value to ensure that the target will not be broken. Under the same driving force, the basic factor determining the clamping force is the size of the manipulator. The key to determine whether the goal can be perfectly picked is whether the joint size of the manipulator is reasonable or not. So for picking different fruits, the clamping force needed is different [10]. For picking different targets, the design of clamping force has become one of the keys to the design of end effector.

7. outlook

Through the above comparative analysis, the design level of the end-effector of various fruit and vegetable picking robots at home and abroad still has great room for improvement. It can be further improved according to the needs of future agricultural economic development, so as to enhance the perception and recognition ability of the end-effector of the picking robot, ensure that the end-effector of the fruit and vegetable picking robot can accurately control the picking process and reduce the damage to the fruit. The end-effector for picking fruits with similar shape can be developed, such as picking apples, oranges, tomatoes and other spherical fruits with the same end-effector or picking eggplants, cucumbers and other long strip fruits with the same end-effector, so as to enhance the versatility of the end-effector of the picking robot.

Reference:

[1] M MONTA, N KONDO and K C TING. End-Effectors for Tomato Harvesting Robot [J] Artificial Intelligence Review,1998 (12): 11-25.
[2] N Kondo, K C Ting. Robotics for Bioproduction System [M]. ASAE, 1998.
[3] Peter P Ling, Reza Ehsani, K C Ting, et al, Sensing and End-Effector for a Robotic Tomato Harvester [C]/ ASAE An-nual International Meeting, Ottawa Canada, 2004.
[4] Yoshihiko Takahashi, Jun Ogawa, Kouichi Saeki. Automatictomato picking robot system with human interface using im-age processing [C]/ The 27th Annual Conference of the IEEE Industrial Electronics Society, 2001.
[5] Naoshi Kondo, Kazuya Yamamoto, Koki Yata, et al, A Ma-chine Vision for Tomato Cluster Harvesting Robot [C]/ AnASABE Meeting Presentation, 2008.

[6] Liu Jizhan, Li Pingping, Li Zhiguo. Hardware design of the end effector of Tomato Picking Robot [J]. Journal of Agricultural Machinery, 2008, 39 (3): 109-112.
[7] Leige, Yin Fenglai. Application Status and Key Technologies of Intelligent Manipulator [J]. Wireless Interconnection Technology, 2019 (4): 133-134.
[8] Xiao Yingkui, Li Yongqiang, Xie Long, et al. Research on a new force-sensing flexible fruit and vegetable picking manipulator [J]. Agricultural mechanization research, 2017 (10): 133-136.
[9] Jia Weikuan. Target recognition of apple picking robot based on intelligent optimization [D]. Zhenjiang: Jiangsu University, 2016.
[10] hang Kailiang. Design of end effector of strawberry harvesting robot [J]. Agricultural mechanization research, 2009, 31 (4): 54-60.