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Design of Tomato Picking Manipulator

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Abstract: Tomato Picking Robot is a type of robot. It can work in a special environment, and it is a milestone in the aspect of agricultural intelligence and automation. According to the environment and condition of tomato growth, the requirements and characteristics of Tomato Picking, the manipulator suitable for picking tomatoes was designed. Finally, the 4DOF redundant manipulator is selected, and the manipulator's type and size design are completed according to the actual situation. In this paper, the basic parameters of the tomato picking manipulator are selected, and the drive mechanism and end effector are analyzed and designed. Through calculation and analysis, selected for motor drive mode; in order to reduce the weight of arms designed within the skeleton; the wrist in order to have a better blessing ability, the parallel gripper, and a sucker at the end. The Tomato Picking machinery arm studied in this paper can also be used for picking other fruits.

Keywords: tomato picking manipulator, manipulator mechanism, end effector, technical parameters.

1. INTRODUCTION

At present, a basic development trend of China's agriculture is automation, mechanization and internationalization. The development of modern science and technology and the transformation of agricultural production patterns have prompted the progress of agricultural machinery. At the same time, the requirements for the intelligence and automation of agricultural machinery are also increasing. As an achievement of the new era, agricultural robots have a vast and beautiful application market in agricultural machinery.

The use of agricultural robots has also brought us a lot of benefits. It not only solves the problem of dealing with labor shortage, but also improves work efficiency and quality, improves the production environment, and prevents harmful substances from harming people's health. Therefore, The research of tomato picking robot not only has theoretical significance, but also has practical application value.

2. SELECTION OF BASIC TECHNICAL PARAMETERS OF TOMATO PICKING ROBOT

2.1 Select the driving method

The selection of the tomato picking robotic arm drive system should be considered based on its performance requirements, control functions, operating power consumption, application environment and operational requirements, performance-cost ratio, and other factors [1]. Due to the complex and compact structure of the hand, the accuracy of the movement of the hand's opening and closing degrees of freedom is not as high as that of the joints. Therefore, the hand uses open-loop control. Since the wrist joint needs to output a certain torque, the motor that drives the pitching operation must also ensure that the self-locking is achieved when the power is turned off. Therefore, the stepping motor is selected.

2.2 Tomato picking robot operation requirements

The picking process of the tomato picking robot in this paper is similar to the process of human picking the tomato. The robot arm is equivalent to the human arm. The robot's picking action and posture are consistent with the human picking. The operation requires not only the tomato to be picked but also the tomato picking. Do not damage the tomato.

Therefore, we designed the following block Fig. 2-1 for the above requirements. This block diagram clearly shows the entire picking process:

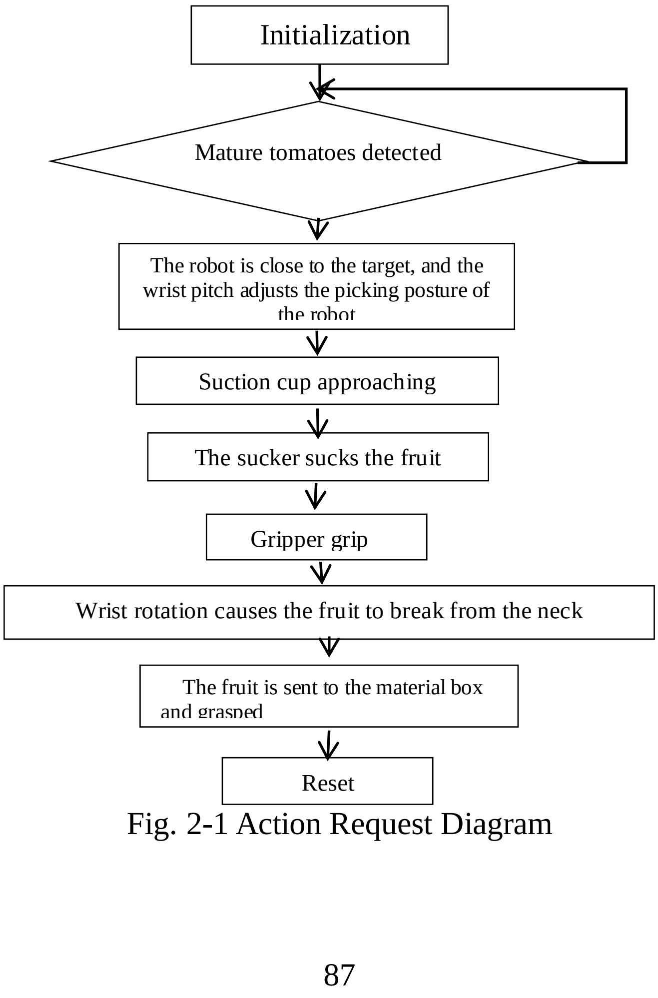


Fig. 2-1 Action Request Diagram

2.3 Preliminary estimation of rated speed

After the maximum stroke of each action of the manipulator is determined, the time of each action is determined according to the cycle time schedule, and the motion speed of each action can be further determined, expressed in m/s, and the time distribution of each action needs to consider various factors.

Because each picking takes about 15s, the robot can work 18 hours a day, the moving speed is set at about 0.8m/s, and the robot should stop advancing and picking and collecting fruits for every 0.3m. Therefore, in order to ensure the quality of the fruit, the speed and acceleration of picking must be limited, initially set at less than 1 meter/second. This value is guaranteed by each joint motor.

Based on the compression characteristics of tomato fruit at different maturity [2] and the maximum breaking stress of tomato [3], the mean value of the maximum breaking force of tomato is determined:

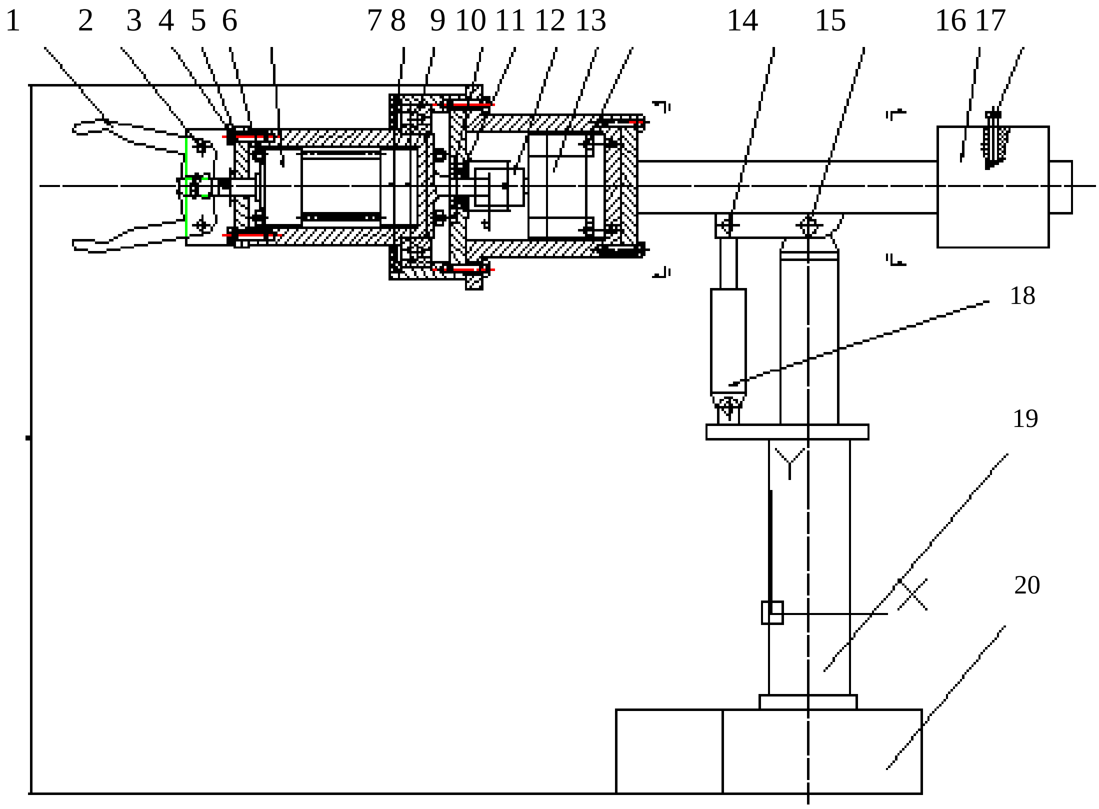
$$\overline{F} = \frac{\sum_{i=1}^{n} F'_{\max}}{n} = \frac{(30.95+30.40+36.98+29.27+37.41)}{5} = 32.93N$$

In order to ensure that the end effector can have sufficient strength, take the safety factor: $K = 1.2$ .Then, first estimate the holding force of the end effector is: $F = \overline{F} \times K = 32.93 \times 1.2 = 39.52N$,and round the result to: $F = 40N$.

Through the research and calculation in this chapter, the final selected driving method is the motor drive; the actual picking process of the tomato picking robot simulates the actual manual picking process, and the flow is similar; the initial estimated speed is $0.8m/s$; the initial estimation of the fruit's clamping force is $40N$.

3. MECHANISM DESIGN OF TOMATO PICKING ROBOT

Robot mechanism design is also called mechanism synthesis and mainly includes type synthesis and size integration. The type and size of the robot mechanism determine the manipulator's operating characteristics and the position of the end effector [4]. The harvesting robot is mostly a space open chain mechanism to meet a certain performance requirement. At the same time, it is necessary to consider the form of the motion manifold and the end effector [5] to meet the posture requirements. This chapter is based on the biological characteristics of tomato and cultivation methods, follow the principles of institutional design, the tomato harvesting robot arm is divided into two parts of the arm and wrist were selected, size parameters according to the actual application to determine. The overall assembly drawing of the robot designed in this paper is shown in Figure 3-1:



1. Gripper 2. Cylindrical pin 3. Bolt 4. Washer 5. Nut 6. Hydraulic cylinder 7. Stopper 8. Bearing 7012C 9. Bearing 7000C 10. Stopper 11. Coupling 12. Motor 13. Screw 14. Cylindrical Pin 15. Cylindrical Pin 16. Counterweight 17. Bolt 18. Hydraulic cylinder 19. Column 20. Base

Figure 3-1 Overall structure of tomato picking robot

3.1 Mechanical design of tomato picking robot

Tomato biological characteristics, cultivation methods and other factors are the basis and premise of organization selection, and determine the structure and working methods of robot manipulators. The default cultivation method here is ground cultivation. The type synthesis is to determine the freedom of the manipulator mechanism, the composition type, the number of joints and the configuration mode according to the operation requirements before determining the robot mechanism parameters [6]. Tomato harvester robot type synthesis, first combined with the biological characteristics of tomato, work requirements and work characteristics, analysis of the characteristics of various types of institutions, to find a variety of robotic mechanisms to meet operational requirements, and then conduct preliminary performance analysis and comparison of selected institutions. The mechanism of tomato picking robots selection mainly includes the degree of freedom, wrist type and arm type selection.

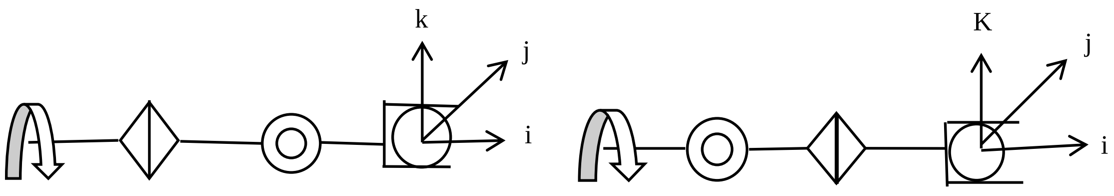
3.1.1 Degree of freedom choice

In order for the manipulator to reach any given position in space, the arms of the space manipulator should have at least 3 degrees of freedom. The degree of freedom of the wrist is mainly used to adjust the posture of the end effector in the space. In order to make the hand in any desired posture in space, the wrist should have three degrees of freedom in theory, and the spherical auxiliary body rotating around the three axes is the most Ideal, but the spherical surface cannot be driven by uniaxial rotation. Therefore, it is actually replaced by three rotating pairs, which is three rotating joints. These three rotating joints can be intersected at one point but not at a single point. , so usually the wrist has at least 3 degrees of freedom. However, the degrees of freedom can be appropriately reduced for practically different job types and job requirements, typically 0-3.

3.1.2 Robot Mechanism Type

① wrist type

The end effector simulates the human hand movement, first grasps the fruit, and then completes separation of the fruit and the pedicel. This process requires the wrist to perform two rotations around the j axis and around the i axis. There are two types of wrists to achieve this movement, as shown in Fig. 3- 2 shows.



Type 1 Type 2

Fig. 3-2 Wrist structure

② arm type

The four types of manipulator arm are called rectangular coordinate type, cylindrical coordinate type, polar coordinate type, and joint type arm. It is the most basic type of manipulator. The arm structure type is not necessarily only the above four basic types. Two basic types of combinations can be selected. Made, or other types that can meet the requirements.

There are five types of mechanisms that can be used as tomato harvest robot arms, as shown in Figure 3-3:

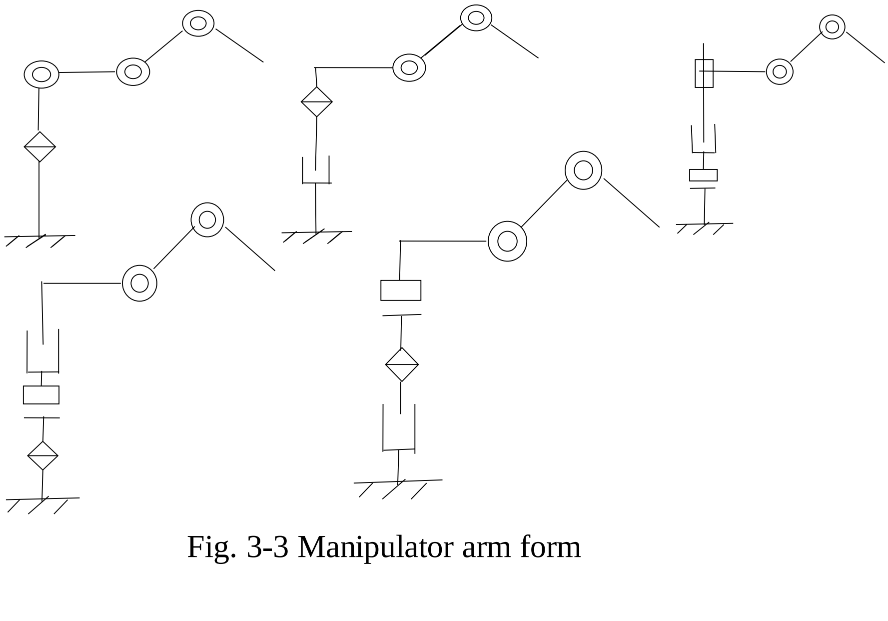


Fig. 3-3 Manipulator arm form

In Fig. 3-3, the interference of the arm in the corresponding posture of the end-bar can be expressed as:

$$A_i = 0, A_j = 1, A_k = 1$$

Among them, Al is the interference of the arm joint to the end shaft in the direction of the corresponding l axis, $A_l = 1$ indicating interference, $A_l = 0$ indicating no interference.

3.2 Robot mechanism type

After arm and wrist selection, the combination of the two must meet the requirements of the posture, not simply installed into one. The rotation of the wrist satisfies the posture requirement of the working object and can be expressed as:

$$W_1 \geq B_1,\ l = i, j, k$$

In the formula, B_l is the rotation required to achieve the target object posture; $B_l = 1$, means that the need to rotate around the l axis, $B_l = 0$,indicating that the l axis does not rotate, $B_l = -1$,allowing arbitrary rotation around the l-axis;

According to the action characteristics of manual picking tomato, when the tomato harvester picks the operation, the required rotation is:

$$B_i = 1,\ B_j = 1,\ B_K = -1$$

Movement of the joints of the arms may cause interference with the posture of the end bar. This interference must be compensated by the rotation of the wrist, ie:

$$W_l \geq A_l\ ,\ l = i, j, k$$

Therefore, when the robot mechanism is integrated, the posture requirements must be met:

$$W_l \geq A_l + B_l,\ l = i, j, k$$

According to the above formula, the combination of the wrist type l and any one of the arm types does not meet the requirements. The combination of wrist type 2 and arm type can be used as the structure of tomato harvesting robot, as shown in Figure 3-4 below:

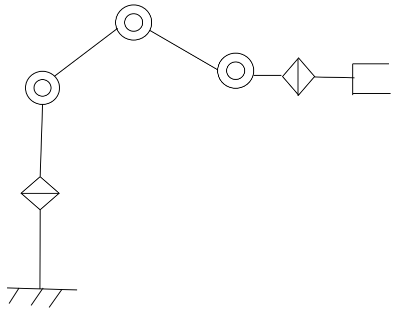


Fig. 3-4 Tomato harvester robot type

After the research on the biological performance of tomato and the requirements of picking operations, the range of degrees of freedom of the Manipulator wrist mechanism was finally determined to be 0-3; according to the comparison of the wrist and arm of the manipulator, the type of the mechanism of the wrist is selected as the first type, the mechanism of the manipulator The type has selected a four-axis robot.

4. DESIGN OF END EFFECTOR STRUCTURE

Whether clamping or adsorption, the end effector has sufficient holding (adsorption) force and required clamping position accuracy to meet the needs of the job. The end effector should be as simple, compact, and lightweight as possible to reduce the load on the arm. The special end effector has a simple structure and high work efficiency. The "universal" end effector capable of performing a variety of tasks may bring about the disadvantages of complicated structure and high cost. Therefore, it is advocated to design a serialized and general purpose dedicated terminal that can be quickly replaced.

The mechanical grippers used in robots are mostly two-finger grippers, which can be divided into a translational type and a rotary type according to the movement of their grippers. Rotary grippers can be divided into single-point pivot type and double-point pivot type, and can be divided into outer clip type and inner type. There are three kinds of electric (or electromagnetic), hydraulic and pneumatic [7] according to the driving mode. The rotary type holder has a simple structure but has a certain clamping error, and does not generate errors for the translating type holder. Therefore, the translating type holder is widely used.The left-hand thread of the translatory gripper is not easy to machine, and the motor easily generates eccentric forces on the end effector. Therefore, considering the synthesis on the basis of this, a screw-drive type translatory gripper was designed.Because in the process of picking, the sucker is close to the target tomato and sucks it, so the sucker must choose good buffering performance and strong vacuum suction. Therefore, the sucker here selects the corrugated suction cup.

5. CONCLUSION

(1) Completed the selection of the basic technical parameters of the tomato picking robot. The final selected driving method is motor drive; the actual picking process of the tomato picking robot is similar to the manual picking mode; the rated speed is $0.8m/s$; The holding force of the fruit is $40N$.

(2) Analyze and design the end effector of the important part of the manipulator, comprehensively consider all aspects, and finally select the screw drive type translating holder and add the suction cup to make it have good clamping performance. The arm part adopts the inner skeleton type design, which can effectively reduce the mechanical weight. Lowering the center of gravity of the robot increases its flexibility.

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