Construction and Analysis of Transplanting Robot Actuator Control System Based on Machine Vision

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Abstract. Automated transplanting robots can liberate human labor and rapidly increase the speed of transplantation. This paper aims at the application of mechanical arms in transplantation by analyzing the force of the actuator during the transplantation process, and combines with the kinematics analysis of the actuator to create a control system for transplanting robot actuators based on machine vision, then simulates and verifies the transplanting robot actuators and control system, the result shows that the transplanting function is stable and the effect on plant protection is good.

1. Introduction
Transplanting is a very simple operation, but it is very time-consuming and needs to be done carefully. The manual transplantation requires a lot of manual work and is very time-consuming. The automated transplanting robot can free human labor, increase the transplanting speed by 4-5 times and stabilize the transplanting quality [1,3].

In order to achieve the realization of automatic transplantation, experts and scholars at home and abroad have done a lot of researches. Tong JH et al. designed a force measurement platform based on a universal testing machine with an adjustable pointer to hold the compressed seedlings, and established a mechanical transfer model to obtain the clamping force of the pointer on seedlings;[4] Yu Y F et al. used extra green feature segmentation method to analyze the color images of plant seedlings in the bowl, and finally concluded that the best method for determining the position of seedling rhizomes is a morphological algorithm;[5] Feng SJ et al. proposed a new 3CRR parallel structure, and applied it in the field of seedling transplanting. However, as far as the current development of transplanting automation is concerned, there is still a long way to go to achieve full automation of transplanting. [6] Aiming at the application of actuators in transplantation, this paper proposes a robot-vision-based actuator for transplanting robots, and fully analyzes and tests its control system and mechanical structure.

2. Mechanical structure design of transplanting robot actuator
According to the actual environment, obtain the design parameters of the actuator to analyze and design the mechanical principle of the system, then the design effect of the actuator can be obtained as shown in figure 1, the degree of freedom f=6, and the number of joints is set to 3, to realize rotating and grasping in all directions, so as to realize the transport function of potted plants.
1. Stepper motor 2. No. 1 steering gear 3. No. 2 steering gear 4. No. 3 steering gear 5. No. 4 steering gear 6. No. 5 steering gear

**Figure 1.** 3D drawing of the actuator.

At the motor output shaft end, the motor is connected to the potentiometer through a gear transmission. The model of the reduction motor is a GM37-520 DC reduction motor. Its parameters are shown in Table 1.

| Table 1. Parameter of motor. |
|-----------------------------|
| Parameter                   | Value          |
| Rated voltage               | 12V            |
| Unloaded speed              | 49r/min        |
| Rated load speed            | 31r/min        |
| Rated torque                | 686.3kg•cm     |
| Rated current               | 0.45A          |
| Lock-rotor torque           | 28kg•cm        |
| Lock-rotor current          | 2.4A           |
| Reduction gear ratio        | 1:150          |

2.1. Mechanical analysis of actuator

The schematic diagram of the actuator is shown in Figure 1. During the robot transplanting process, the steering gear of No.1 and No.2 have large loads. So the mechanical analysis of the actuator is carried out to calculate whether the load torque of the steering gear is greater than the rated torque, which is necessary for the design of the actuator system.

Taking the servo No. 2 as an example, the distance from the steering gear No. 2 to the equivalent load center is L, and the load is G, so the load moment M of the servo No. 2 can be obtained as follows: $M = L \times G$, the mechanical diagram can be shown as in figure 2.

**Figure 2.** Mechanical diagram.
2.2. Kinematics analysis of the actuator system
The entire link of the series-connected actuator is composed of a set of connecting rod rigid bodies. The connecting rods are connected by joints (kinematic pairs), and each joint has one degree of freedom of translation or rotation. The movement of a joint changes the relative angle and position of its adjacent link. The arrangement of the four joints is shown in figure 4-4. The shoulder and wrist joints are in the same plane. Z1, Z2, and Z3 in the orthogonal diagram of the shoulder and elbow joints correspond to the shoulder, elbow, and wrist drive shafts, and Z is the direction of rotation of the joint.

![Figure 3. Schematic diagram of actuator joint arrangement.](image)

To study the displacement relationship between the links of the manipulator and perform the kinematics analysis, we use the Denavit and Hartenberg parameter method, then fix a coordinate system on each link, and use the $4 \times 4$ homogeneous transformation matrix to describe the spatial pose of the two links, finally derive the equivalent homogeneous transformation matrix of manipulator end coordinate system relative to reference system.

3. Construction of actuator control system for transplanting robots
The transplanting robot actuator has a total of 6 degrees of freedom and uses 6 motors, including 1 stepper and 5 steering gears. In order to achieve the control of the actuator, the overall architecture of the control system is shown in figure 4. It consists of six parts: power supply, STM32 micro-controller, TB6600, host computer, stepper motor and steering gears. STM32F103 micro-controller controls the stepper motor driver TB6600 through PWM. TB6600 drives the stepper motor by receiving STM32 control instructions, thus achieving 360° rotation of the actuator. In addition, the STM32F103 micro-controller controls the steering gear control board through serial communication. The steering gears control board communicates with the host computer via USB (Universal Serial Bus) to realize the debugging and download of the action group, by receiving STM32 control instructions to drive the steering gear, so as to achieve the functions of grabbing and dropping.

![Figure 4. Overall architecture of the actuator control system.](image)
The stepper motor drive controller hardware circuit includes STM32 control module, opt coupler isolation module and LV8727 drive module. The frequency of the PWM pulses generated by the STM32 timer is determined by the clock frequency \( f \), the prescaler value \( M \) and the counting period \( T \). The relationship is as follows. As shown in equation (1), the PWM frequency can be changed by changing the prescaler value \( M \).

\[
V = \frac{f}{(M + 1)(T + 1)}
\]  

(1)

STM32 micro-controller’s system consists of ① main chip, ② power-on reset circuit, ③ clock circuit, ④ power supply circuit. The clock circuit shown in figure 6 uses an 8MHz crystal as the main frequency and 32KHz as the clock RTC frequency. According to the chip manual, it can be known that the main chip is reset at a low level, and the CREST terminal of the reset circuit is connected to the reset pin of the 7th pin of the main chip. At the moment of power-on, C2 is equivalent to the grounding of the channel, and the chip is automatically reset, after that VDD stabilizes, C2 is equivalent to an open circuit, and the reset terminal CREST is always high. The power-on reset circuit is shown in Figure 5.

4. System overall control process

The transplanting robot performs the process of grabbing and handling the potted plant, the control flowchart is shown in figure 7. After the OpenMV module of the transplanting robot recognizes the potted plant, it sends a stop signal to the STM32 through level communication, so that the STM32 can control the DC motor to stop rotating, the STM32 controls the robotic arm control system to achieve the grasping of the potted plant. After the grasping function is successfully performed, the STM32 controls the DC motor to move to the storage area to complete the process of grasping and transporting the potted plant.

![Figure 5. Power-on reset circuit.](image)

![Figure 6. Clock circuit.](image)

![Figure 7. Overall control flow of the system.](image)
5. Conclusion
This paper aims at the application of the robotic arm in transplanting. By analyzing the force of the actuator during the transplanting process and combining the kinematics analysis of the actuator, a control system for the transplanting robot actuator based on machine vision is constructed. The overall control process of the robot system is analyzed and discussed, and the following conclusions can be obtained:

1) This paper introduces the mechanical and kinematic analysis of the robotic arm of the transplanting robot, and builds a control system for the actuator of the transplanting robot based on machine vision based on this.

2) The simulation of the actuator and control system of the transplanting robot is carried out to verify that the transplanting function is stable and the plant protection effect is good.

The control system proposed in this study is not only suitable for robot actuators for transplanting, but also for robot actuators such as logistics handling. This paper only proposes a robot actuator control system. In the subsequent research, a closed-loop control system will be constructed by combining fuzzy and robust control to further improve the stability and accuracy of the actuator.

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