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RESEARCH ON TEACHING ROBOT BASED ON SERVO MOTOR DYNAMIC BALANCE

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Aiming at the problems of complex teaching trajectory, many teaching points and long teaching period, a series robot with direct teaching was developed. The configuration, 3D model and balance scheme of the robot's mechanical structure are designed. The dynamics of the robot is analyzed by Lagrange method, and the Monte Carlo workspace of the robot is analyzed based on MATLAB platform.

Keyword: mechanism structure, dynamics, work space

INTRODUCTION

With the improvement of living standards, people's demand for various products is becoming more and more diversified and personalized, so robots need a more rapid and economical teaching method to adapt to the rapid update of products [1]. For products with large dimensions and complex surfaces, the teaching box is cumbersome and inefficient. The virtual teaching cost is high and the period is long. The direct teaching efficiency is high, but the torque sensor or measuring arm is expensive, and the reducer of the robot causes large joint reaction force, which makes the labor intensity high [2,3]. In order to give full play to the advantages of direct teaching, a new type of mechanical structure is developed, aiming at simple structure, economy and easy operation to meet the actual needs of products [4,5]. The robot uses servo motor to directly connect with the joint of the large and forearm to balance the gravity of the joint; The structure of the wrist is consistent with the action of the direct teaching process. During teaching, the instructor drags the end of the robot, and the computer continuously collects the Angle of the encoder and downloads it to the controller of the robot [6].

ROBOT MECHANISM AND 3D MODEL

The configuration of the robot teaching mechanical structure is shown in Figure 1. The first three joints of this configuration are used as positioning mechanisms to determine the position of the end in space; The rear three joints serve as orientation mechanisms to determine the position of the end in space. By analyzing the motion process of the robot, it is found that the pitching joint and the swinging joint are placed at the end in combination with the maneuverability of the hand pulling the end directly.

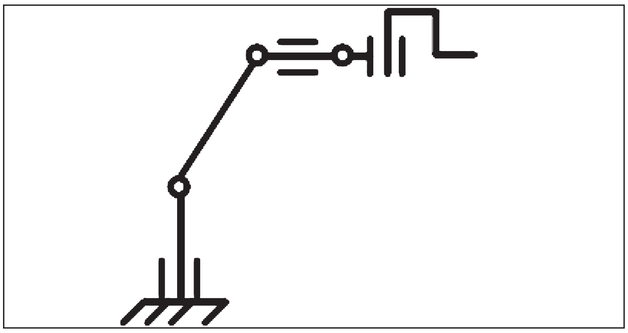

Figure 1 Robot mechanism configuration

The overall model of the robot is shown in Figure 2, which mainly consists of the fuselage rotating joint, the big arm joint, the forearm joint and the wrist joint. The size of the robot is combined according to the mechanical structure configuration, and the gravity of the forearm motor, the position of the encoder, and the routing of the cable are considered. The installation position of the forearm motor is designed at the joint of the forearm, and the synchronization belt and pulley are connected with the joint of the forearm. The robot is designed as a hollow structure, the encoder is placed inside the mechanism, and the hollow structure is used for cable routing.

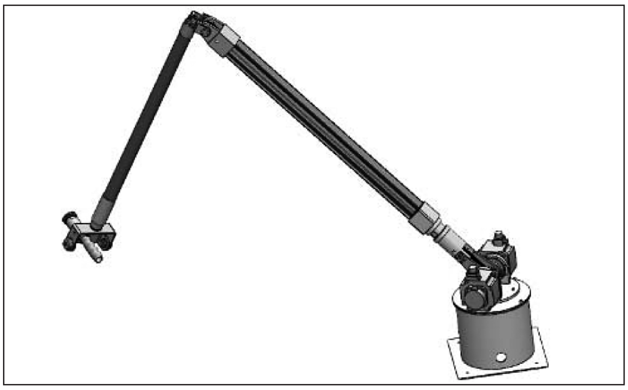

Figure 2 Robot 3D model

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ROBOT DYNAMIC BALANCE DESIGN

When teaching, the instructor uses the torque mode of the servo motor to help the robot. The complete dynamic model is as follows:

$$\tau_d + \tau_s - \tau_m + \tau_w = M(\ddot{q}) + C(q, \dot{q}) + G(q) \quad (1)$$

Where τ_d is Torque of servo motor; τ_s is External torque of teaching personnel; τ_m is friction torque between mechanisms; τ_w is Calculating error torque; $q, \dot{q}, \ddot{q}$ are joint Angle, angular velocity, angular acceleration; $M(q)\ddot{q}$ is inertial force term; $C(q, \dot{q})$ is Coriolis force and centrifugal force terms; $G(q)$ is Gravity term; τ is Joint driving torque.

At this time, the external torque of the instructor offsets the friction torque between the mechanisms and the calculated error torque, that is, the servo motor is only used to offset the torque of the robot itself:

$$\tau_d = M(\ddot{q}) + C(q, \dot{q}) + G(q) \quad (2)$$

The control system built based on encoder feedback is shown in Figure 3. In the torque mode of the servo motor,

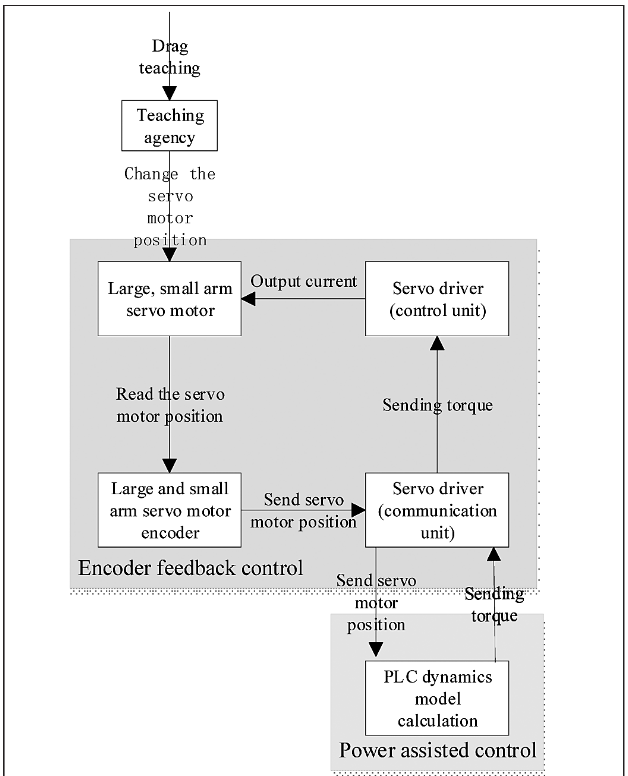


Figure 3 Control system based on encoder feedback

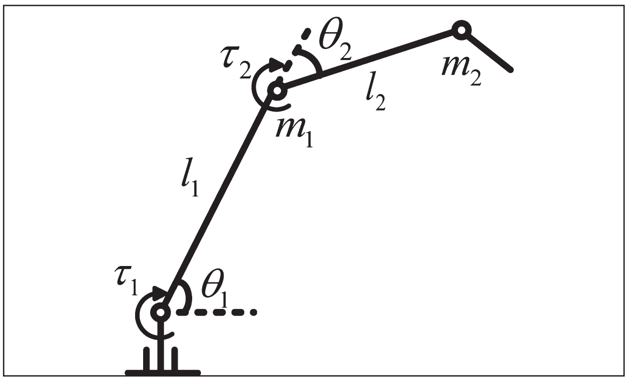
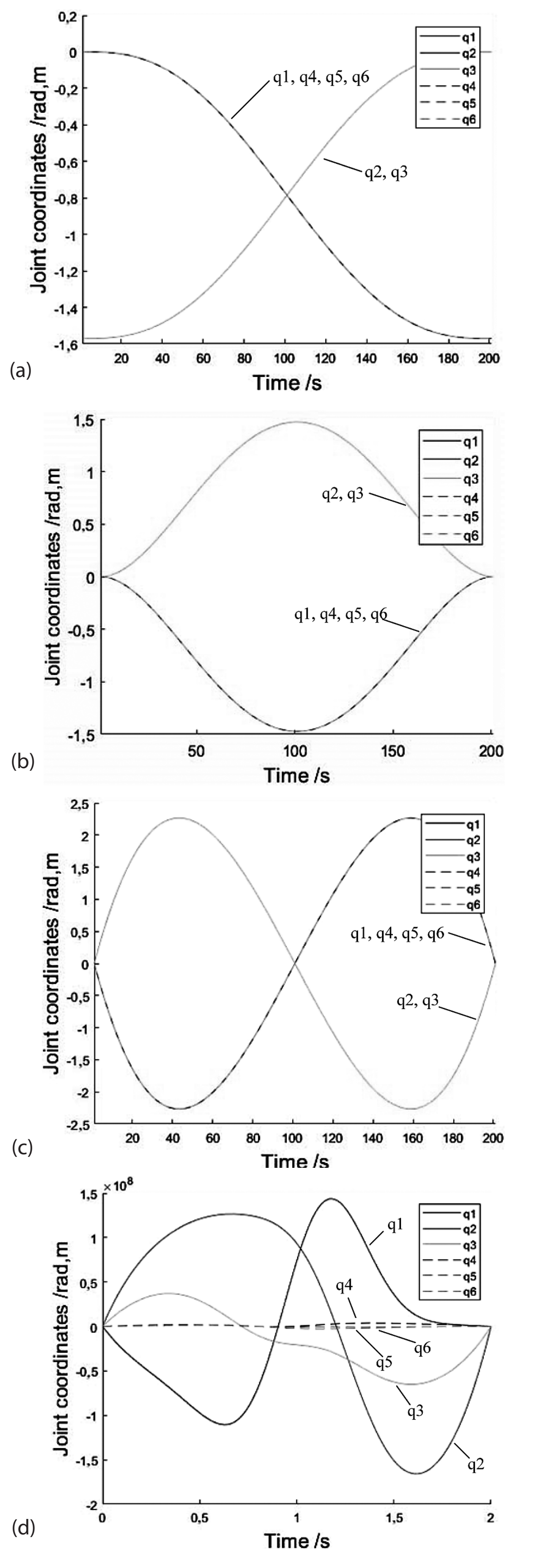


Figure 4 Schematic diagram of robot structure



(a) Joint position (b) Joint velocity (c) Joint acceleration (d) Joint torque

Figure 5 Robot dynamics solution

the servo driver continuously samples the encoder at high frequency and sends it to the PLC. The PLC solves the dynamics model and sends the resulting torque to the servo driver, and the driver calculates the corresponding current to control the servo motor to realize the robot's power.

For the convenience of calculation, the wrist joint used for attitude control is simplified into a whole. It is assumed that the mass of the upper arm joint is concentrated in the upper arm end. The mass of the forearm joint and wrist joint is concentrated in the wrist center. At this time, the structural sketch of the robot is shown in Figure 4.

The Lagrange method is used to model the dynamics model of the robot:

$$L(\Theta,\dot{\Theta}) = K(\Theta,\dot{\Theta}) - P(\Theta) \tag{3}$$

$$\tau = \frac{d}{dt}\frac{\partial L}{\partial \dot{\Theta}} - \frac{\partial L}{\partial \Theta} = \frac{d}{dt}\frac{\partial K}{\partial \dot{\Theta}} - \frac{\partial K}{\partial \Theta} - \frac{\partial P}{\partial \Theta} \tag{4}$$

Where L is Lagrange operator; K, P is kinetic energy, potential energy; Θ is joint variable, the displacement or angle of the joint; $\dot{\Theta}$ is velocity or angular velocity; t is time; τ is joint driving force.

The robot dynamics model is calculated as follows:

$$M(q)\ddot{q} = \begin{bmatrix} m_1 l_1^2 + m_2(l_1^2 + 2l_1 l_2 \cos\theta_2 + l_2^2) & m_2(l_1 l_2 \cos\theta_2 + l_2^2) \\ m_2(l_1 l_2 \cos\theta_2 + l_2^2) & m_2 l_2^2 \end{bmatrix} \tag{5}$$

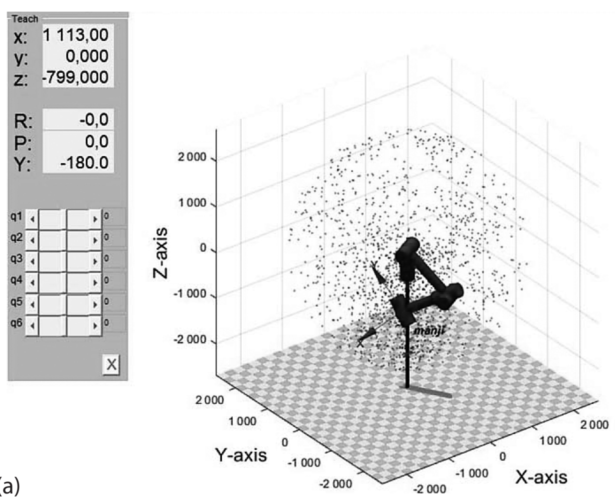
$$C(q,\dot{q}) = \begin{bmatrix} -m_2 l_1 l_2 \sin\theta_2 (2\dot{\theta}_1\dot{\theta}_2 + \dot{\theta}_2^2) \\ m_2 l_1 l_2 \dot{\theta}_1^2 \sin\theta_2 \end{bmatrix} \tag{6}$$

$$G(q) = \begin{bmatrix} (m_1 + m_2) g l_1 \cos\theta_1 + m_2 g l_2 \cos(\theta_1 + \theta_2) \\ m_2 g l_2 \cos(\theta_1 + \theta_2) \end{bmatrix} \tag{7}$$

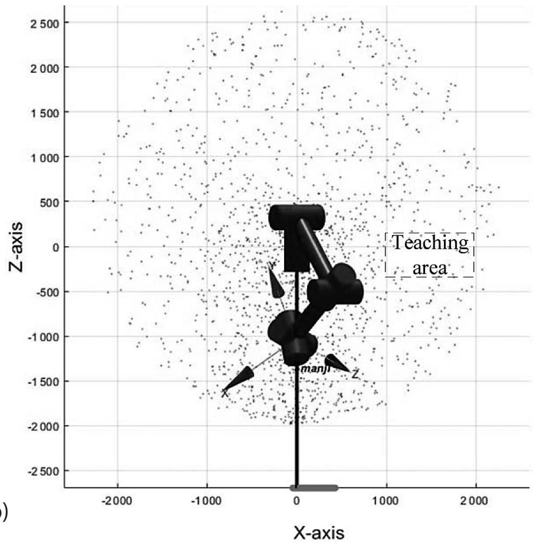
Physical parameters such as the position of the centroid of each joint and the inertia matrix calculated by Solid Works software are brought into the robot model established by Matlab robot toolbox. Firstly, a motion trajectory is designed for the teaching mechanical structure model, and then the position, velocity, acceleration and other information of each joint of the robot are obtained by solving the inverse kinematics. Finally, the torque of each joint is drawn by using the Matlab platform through the dynamics model of the robot, as shown in Figure 5.

ROBOT WORKSPACE ANALYSIS

The Monte Carlo method is used to study the robot workspace, and the robot toolbox of Matlab is used to generate visual workspace images. By determining the



(a)



(b)

(a) Work space (b) X-Z direction work space

Figure 6 Robot Monte Carlo workspace

range of motion of each joint of the robot, the random number generated by rand() function is multiplied with the range of motion of the joint, and the random joint Angle is obtained. Repeat the above steps to draw the 3D image of the robot workspace through the plot3() function, as shown in Figure 6.

As can be seen from Figure 6, its working space covers the teaching area, that is, the working space of the robot, which can meet the direct teaching requirements of the robot.

CONCLUSION

By analyzing the motion process of the robot, the mechanical structure is designed to simulate the manual dragging and teaching, and the overall model of the robot is designed according to the size parameters of the robot. The servo motor is directly connected to the joint, and the dynamic balance of the robot is realized by using the torque mode of the servo motor. The dynamics model and working space of the robot are analyzed by Matlab platform, and the feasibility of the robot is verified.

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Note: The responsible translator for English language is Q. ZHANG-North China University of Science and Technology