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The Research on Dynamic analysis and Simulation of Dobot manipulator

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Abstract

In this paper, the D-H modeling method is used to build the kinematic model of the Dobot, and the forward kinematics solution is analyzed. The method of quintic polynomial interpolation is used to plan the trajectory of the Dobot. The simulation analysis is carried out in the MATLAB environment. The results show that the positions before and after the simulation are consistent with the theoretical analysis, which shows that this method It can meet the given requirements and provide a theoretical basis for the future research and development of Dobot.

Keywords

Manipulator, D-H modeling,Trajectory,Dobot.

1. Introduction

Robots are of great significance to modern automatic production and the foundation of the future intelligent society. At the same time, industrial robots have a lot of applications in the current automatic production [1-3]. However, industrial robots are expensive and need to further optimize performance to meet different needs [4]. Therefore, a large number of scholars have invested in the research here. Because of the high price, the development cycle The performance of virtual simulation has been widely used [5-7], using software to draw the three-dimensional trajectory of the robot, and simulated the manual control and trajectory planning of the manipulator model [8-9]. But many researches focus on large robots [8].

In recent years, small desktop robots have attracted more and more attention because of their small size and low price. This paper takes Dobot robot as an example, Using MATLAB robotics toolbox to study the D-H modeling, kinematics, inverse kinematic analysis, trajectory planning algorithm research, simulation and so on of the Robotic Arm. It can also simulate the movement of object modeling according to the mechanical arm model, which provides great convenience and intuitive representation. Verify and simulate the trajectory planning algorithm to get the parameters and end trajectory of the motion.

2. Kinematic analysis of Dobot manipulator

2.1 Modeling of Dobot manipulator

The structure of the machine arm is shown in Figure 1 as the coordinate system control mode. The origin of the coordinate system is the intersection of the three motor axes of the big arm, the small arm and the base. The X-axis direction is perpendicular to the fixed base forward, the Y-axis direction is perpendicular to the fixed base to the left, the Z-axis is vertical to the right, and the R-axis is the position and orientation of the center of the end steering gear relative to the coordinate origin. The counterclockwise is positive, and the clockwise is positive Negative.

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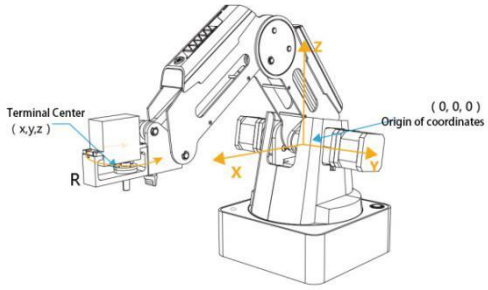

Figure 1. manipulator structure

D-H modeling method is a kind of mechanical arm modeling method proposed by denavit and hartenberg, that is, to establish a coordinate system on each joint, and to establish the coordinate transformation relationship between the two connecting rods through the homogeneous coordinate transformation matrix. In the multi connecting rod series mechanical arm system, the relationship between the end pose of the mechanical arm and the base can be obtained by using the homogeneous coordinate transformation for many times.

Homogeneous coordinate system is to express n-dimension vector in n + 1 dimension. The main advantage of homogeneous coordinate representation method is to unify rotation transformation and translation transformation into 4×4 matrix operation. The homogeneous transformation matrix is as follows:

$$ {}^{j}_{i}T = \begin{bmatrix} * & * & * & * \\ * & {}^{j}_{i}R & * & {}^{j}_{i}P \\ * & * & * & * \\ 0 & 0 & 0 & 1 \end{bmatrix}_{4*4} \tag{1} $$

In the formula, ${}^{j}_{i}T$ represents the pose transformation relation of j coordinate system relative to i coordinate system, ${}^{j}_{i}R$ represents the 3×3 matrix of j coordinate system relative to i coordinate system rotation, ${}^{j}_{i}P$ represents the 3×1 matrix of j coordinate system relative to i coordinate system translation.

According to the size of Dobot manipulator studied, the D-H method is used to establish its model, as shown in Figure 2

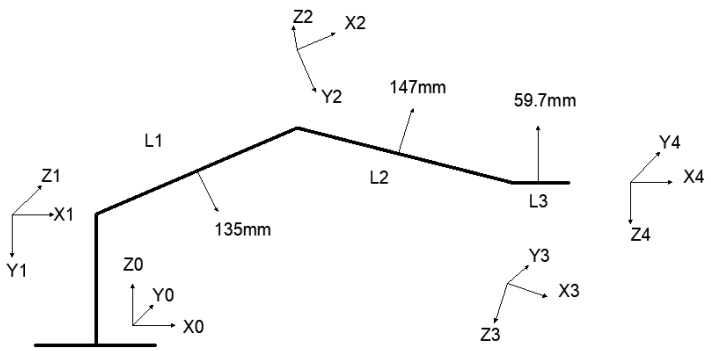

Figure 2. D-H modeling

Its D-H parameter table 1 ,

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Table 1. D-H parameters of Dobot manipulator

L	θ_i	α_i	d_i	a_i
1	θ_1	$-\pi/2$	8	0
2	θ_2	0	0	135
3	θ_3	0	0	147
4	θ_4	$-\pi/2$	0	59.7

According to the D-H parameter table, it is convenient to write out the homogeneous transformation matrix of each transformation, and each row of the D-H parameter table corresponds to a homogeneous transformation matrix. The base coordinate system is coordinate system 0, and the end actuator is coordinate system 4. The homogeneous transformation matrix from coordinate system 0 to coordinate system 4 is recorded as ${}^4_0T$, which represents the position and attitude transformation relationship between coordinate system 4 and coordinate system 0. The final coordinate transformation matrix relationship is as follows

$$ {}^4_0T={}^1_0T\,{}^2_1T\,{}^3_2T\,{}^4_3T \tag{2} $$

2.2 Forward kinematics analysis of Dobot manipulator

The forward kinematics solution is to know the angle and link length information of each joint, and to solve the position and orientation of the actuator at the end of the manipulator relative to the Cartesian coordinate system. According to the D-H transformation rule, the transformation matrix of each coordinate system is respectively

$$ {}^1_0T = A_1 = \begin{bmatrix} c_1 & 0 & -s_1 & 0 \\ s_1 & 0 & c_1 & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3} $$

$$ {}^2_1T = A_2 = \begin{bmatrix} c_2 & -s_2 & 0 & a_2c_2 \\ s_2 & c_2 & 0 & a_2s_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4} $$

$$ {}^3_2T = A_3 = \begin{bmatrix} c_3 & -s_3 & 0 & a_3c_3 \\ s_3 & c_3 & 0 & a_3s_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5} $$

$$ {}^4_3T = A_4 = \begin{bmatrix} c_{23} & -s_{23} & 0 & 0 \\ -s_{23} & c_{23} & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{6} $$

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In the formula, $c_1 = \cos\theta_1$, $c_2 = \cos\theta_2$, $c_3 = \cos\theta_3$, $s_1 = \sin\theta_1$, $s_2 = \sin\theta_2$, $s_3 = \sin\theta_3$, $s_{23} = \sin(\theta_2 + \theta_3)$, $c_{23} = \cos(\theta_2 + \theta_3)$

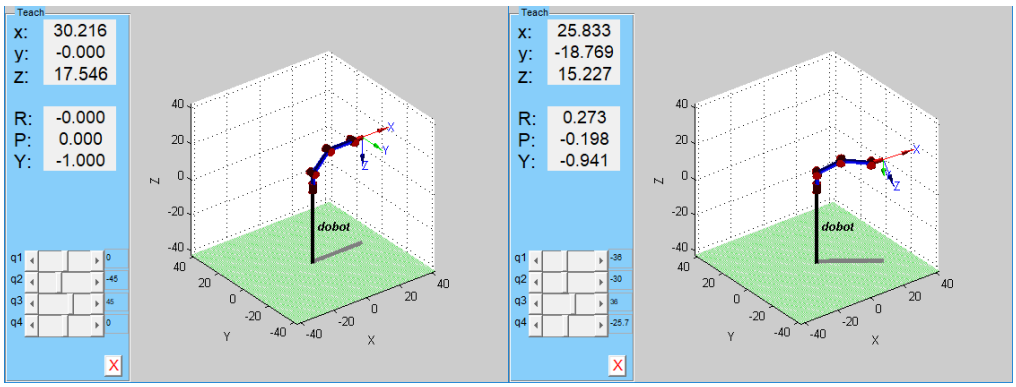
The total transformation between the robot base and the end actuator is:

$$ {}^{4}_{0}T = A_1A_2A_3A_4 = \begin{bmatrix} c_1 & 0 & -s_1 & c_1(a_3c_{23} + a_2c_2) \\ s_1 & 0 & c_1 & s_1(a_3c_{23} + a_2c_2) \\ 0 & -1 & 0 & d_1 - a_2s_2 - a_3s_{23} \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{7} $$

Where, $n = [n_x \quad n_y \quad n_z]^T$ represents the coordinate of X axis in the fixed coordinate system 0 in the dynamic coordinate system 4, $o = [o_x \quad o_y \quad o_z]^T$ represents the coordinate of Y axis in the fixed coordinate system 0 in the dynamic coordinate system 4, $a = [a_x \quad a_y \quad a_z]^T$ represents the coordinate of Z axis in the fixed coordinate system 0 in the dynamic coordinate system 4, and $p = [p_x \quad p_y \quad p_z]^T$ represents the coordinate of the end of the mechanical arm in the fixed coordinate system 0, that is to say, the positive kinematics solution is completed.

3. Dynamics simulation based on MATLAB

In the MATLAB environment, the dobot model with four degrees of freedom is established by using MATLAB robots toolbox. The parameters of each link are: d1 = 80mm, a2 = 135mm, a3 = 147mm. Given the initial position and target position of the manipulator, the trajectory planning in joint space is carried out The variation of each joint is obtained to control the corresponding action of the manipulator, so as to realize the grasping of the target object Assuming that the number of points is 40, the initial joint value is [0 pi / 8 - pi / 2 pi / 3], the end joint value is [pi/5, pi/10, -pi/5, pi/7], the motion trajectory is obtained as follows in Fig.3 by using quintic polynomial interpolation.



(a)Initial pose (b) End pose

Figure 3. Posture after exercise

4. Summary

In this paper, the D-H modeling method is used to build the kinematics model of Dobot, and the forward and inverse kinematics solutions are calculated. According to the working characteristics of Dobot, the method of quintic polynomial interpolation is used to plan the trajectory of Dobot. Finally, matlab robots toolbox is used X toolbox establishes the structure model of Dobot manipulator, verifies the rationality and effectiveness of each parameter of Dobot robot, and carries out trajectory planning simulation. According to the given task requirements, the trajectory planning and Simulation of the robot model are carried out in joint space by using jtraj function, and the pose before and after motion

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is obtained. This method can meet the given requirements, which provides a theoretical basis for the research and development of Dobot in the future.

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