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The kinematics analysis and trajectory planning of Serial Painting robot

Wang Chunyan [1], Xu Yong [2]

[1](*College of Mechanical Engineering, Shanghai University of Engineering Science, China*)
[2](*College of Mechanical Engineering, Shanghai University of Engineering Science, China*)

ABSTRACT: In this paper, a serial robot as the research object, using theoretical analysis, numerical simulation method of combining, to carry out the overall performance analysis and optimization of industrial robots trajectory. For serial robot, kinematics modeling. The establishment of a first-order influence coefficient method based on second-order influence coefficient matrix, kinematic and dynamic analysis of performance indicators based on both Jacobin matrix and Hessian matrix, and the actual size of the work and working space agencies, institutions initially selected size. Finally, institutional performance indicators for institutional map drawing performance, combined with the flexibility and maneuverability determine the size of a set of different institutions in the optimal configuration, and its feasibility through simulation. According to the geometric characteristics of the surface complex surface fragmentation process, solve the optimal value speed and coating spray width of the overlapping area on each patch.

Key words：Serial robot*;* kinematics analysis*; Position;* trajectory planning

I. INTRODUCTIONS

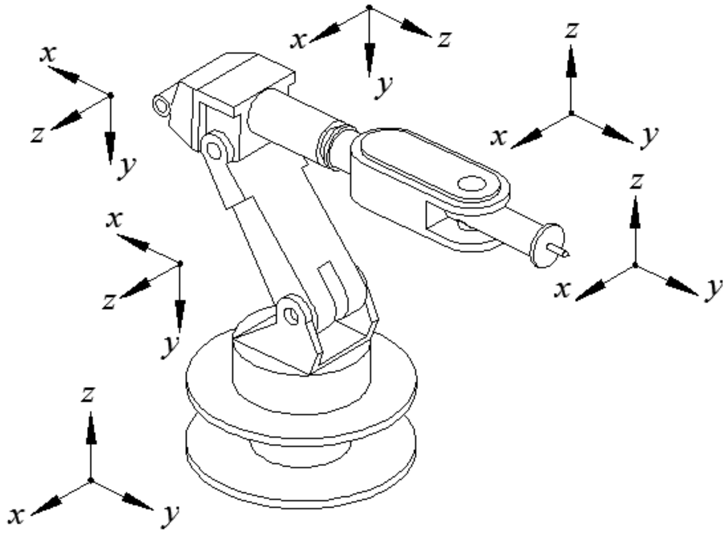
How to improve the performance of the robot's movement has been one of the main issues of concern scholars, but also the research focus in the field of robotics. About sports performance of the robot manipulator, the expert presented a different performance indicators: 1982 Salisbury proposed the concept of the condition number of Jacobian matrix; 1983 and 1985 Yashikawa introduction of the "operational" concept; 1985 Yang defines the robot operand is the condition of this concept; Gosselin in 1991 to optimize the movement of the robot design, defines the global performance indicators. In this paper, the overall performance of kinematic and dynamic properties of a series of research institutions.

First we need to establish the institution of a first, second influence coefficient matrix, and according to the first, second global influence coefficient matrix defined performance indicators and given the global performance of the institution. Since the parameter setting mechanism is reasonable performance directly determining means, the paper size by changing mechanism section member, study its motion in different dimensions of global indicators to explore the performance differences agencies, resulting in a set of different size organization, select sports performance is more excellent institutions.

Meanwhile, in order to make better complete spray painting robot task, but also on the spray trajectory planning, the use of standard spray valve surface fragmentation process, obtaining spray coating speed and the optimal value of the width of the overlapping area of each surface, This will reduce the production cost.

II. Configuration Description

First, for the following figure robot dynamic modeling, as can be seen, the subjects of 6-DOF serial open chain robot, its DH parameter table O-X_0 Y_0 Z_0 polar coordinates, in turn establish joint axis in each joint coordinate system (Figure 1), a_1, a_2, d_1, d_2 structural parameters institutions, θ_1 articular angle, α_1 for the twist angle, the link parameters listed in the table shown below,



Fingure1 The mechanism of the Serial Robot

关节	$a_{(i-1)i}$ / cm	d_i / cm	$\partial_{(i-1)i}$ / (°)	θ_i	关节变量范围 / (°)
1	0	45	0	θ_1	-150~150
2	15	0	90	θ_2	-90~150
3	57	0	0	θ_3	-180~180
4	20	0	90	θ_4	-150~150
5	0	64	-90	θ_5	-180~180
6	0	0	90	θ_6	-200~200
工具	0	17	0	0°	0

Figure 2 link parameter table

While the little robot end effector for the study, according to the established coordinate system transformation matrix required between two neighboring rods. The table parameters are substituted into the coordinate system i and i-l homogeneous coordinate transformation matrix i-1Ai

$$ {}^{i-1}\mathbf{A}_i = \begin{bmatrix} \cos\theta_i & -\cos\alpha_i \sin\theta_i & \sin\alpha_i \sin\theta_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\alpha_i \cos\theta_i & -\sin\alpha_i \cos\theta_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1) $$

The possible transformation matrix,

$$ {}^{n}T_{n+1} = A_{n+1} = Rot_{(z,\theta_{n+1})} \times Trans(0,0,d_{n+1}) \times Trans(a_{n+1},0,0) \times Rot(x,\alpha_{n+1}) $$

$$ A_{n+1} = \begin{bmatrix} C\theta_{n+1} & -S\theta_{n+1}C\alpha_{n+1} & S\theta_{n+1}S\alpha_{n+1} & a_{n+1}C\theta_{n+1} \\ S\theta_{n+1} & C\theta_{n+1}C\alpha_{n+1} & -C\theta_{n+1}S\alpha_{n+1} & \alpha_{n+1}S\theta_{n+1} \\ 0 & S\alpha_{n+1} & C\alpha_{n+1} & d_{n+1} \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

And then find the total transformation matrix： $^{R}T_H = A_1 A_2 A_3 \ldots A_n$

Obtained：

$$
{}^{2}\mathbf{T}_6 = \mathbf{A}_3\mathbf{A}_4\mathbf{A}_5\mathbf{A}_6 = \mathbf{A}_3\,{}^{3}\mathbf{T}_6 = \begin{bmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & c_4s_5 & 0 \\ s_4c_5c_6 + c_4s_6 & -s_4c_5s_6 + c_4c_6 & s_4s_5 & 0 \\ -s_5c_6 & s_5s_6 & c_5 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}
$$

$$
{}^{0}\mathbf{T}_6 = \mathbf{A}_1\mathbf{A}_2\mathbf{A}_3\mathbf{A}_4\mathbf{A}_5\mathbf{A}_6 = \mathbf{A}_1\,{}^{1}\mathbf{T}_6 = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}
$$

III. Kinematics agencies

This paper is based on the use of performance indicators influence coefficient method. When the initial parameters of the mechanism to the timing, influence coefficient method can be obtained in accordance with a first order influence coefficient matrix G of the institution and the second-order influence coefficient matrix H. Here resulting first order influence coefficient matrix (Jacobian matrix) G of 6 × 6 array, the second-order influence coefficient matrix (Hessian matrix) H of 6 × 6 × 6 array. Performance is defined as the impact of the condition number of the coefficient matrix

$$
K_{G_V} = \|G_W\| \bullet \|G_W^{+}\| \tag{4}
$$

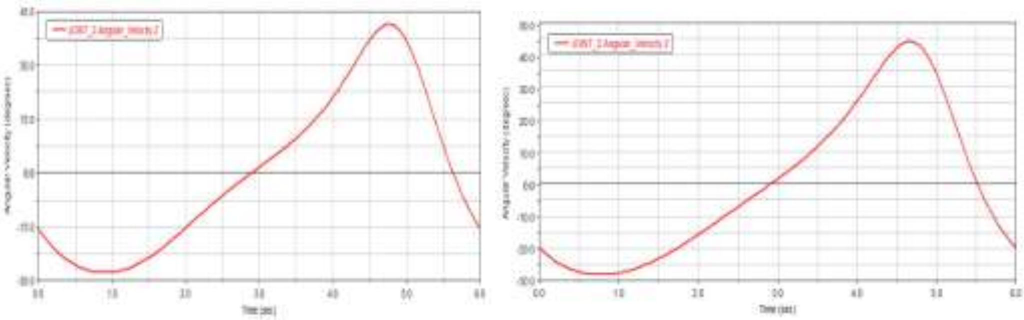
$$
K_{G_W} = \|G_V\| \bullet \|G_V^{+}\| \tag{5}
$$

$$
K_{G_V} = \|H\| \bullet \|H^{+}\| \tag{6}
$$

Wherein, GX is a first order influence coefficient matrix of the Jacobian matrix of the first three rows, G_w ^ + number as the Frobenius norm, G_ + is the generalized inverse matrix; G_v is three lines after the first-order influence coefficient matrix Jacobian matrix, H is Hessian matrix of second-order influence coefficient matrix. Construction serial robot first order influence coefficient matrix, S_j, j = 1,2, ··· 6, can be obtained.

Figure 2 the construction of Serial robot

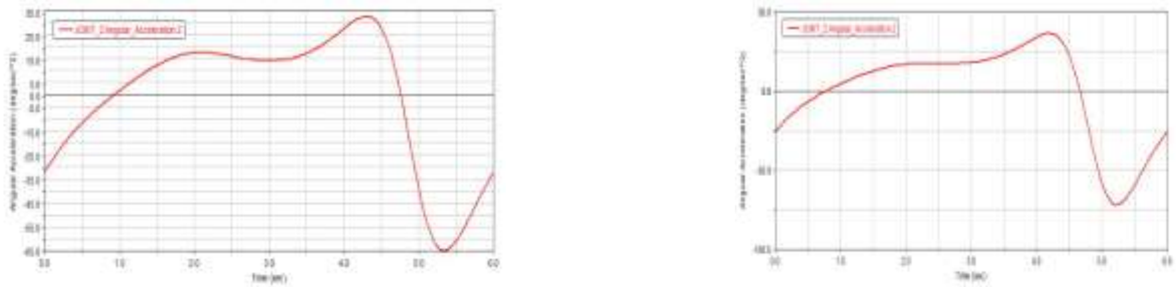
Change posture, setting different agencies size, adjust the parameters in the software, and analyzes the direction of the velocity, acceleration curves, combined with the impact factor performance, robotic systems for global analysis, here select two typical size, and rendering speed graph, it can be seen from Fig first group and the second group, the first group velocity curves gently, the control means is good, on the contrary, more difficult to control the other group configurations. So selecting the first set of dimensions better. Pick perform configuration analysis simulation, one can verify the correctness of the calculation, on the other hand can simplify the design process, while achieving intelligent optimization.



a. The first set of z-direction velocity curve b. a first set of z-direction velocity curve

Figure 3 z direction velocity curve

Below is plotted output different sizes in the Z direction under acceleration curve can be seen from Figure 4, the output of the angular velocity of the first group and the second group compared to flat, which means that the first group than the second group better achieve control, it can be concluded: the first group size is more appropriate.



a. The first set of z-direction Acceleration curve b. a first set of z-direction Acceleration curve

Figure 4 z direction Acceleration curve

IV. trajectory planning

For spray trajectory optimization, will consider the general shape of the workplace, the workplace surface curvature, spray angle and spray distance path several ways, depending on the characteristics of the optimal path, pipeline valve shape is relatively simple, but because of its sheet-like rather than a cylinder workpiece, so when spraying should also consider whether the circumference can be sprayed onto, where the use of this trajectory planning method. With the base coordinate system in the "samples" Cartesian space to regulate and convert it into the joint space, and then use a function method to construct joint variables of curve fitting, and through the controller drives each joint so that the robot end perform the desired trajectory, at a sufficient condition samples, we can guarantee a better approximation robot Upon completion of the specified job task, in addition to the need for accurate implementation of the track, but also consider themselves subject to the robot system constraints, such as work space, speed, acceleration, jerk and torque and other constraints, when the trajectory of the robot to meet these constraints premise, for different job tasks, trajectory planning has different optimization objectives, common optimization goals are: the optimal time, this is to improve the operating efficiency of the system, in many occasions, the optimization index dominated; optimum smoothness, which is to reduce the variation in the robot joint trajectory velocity and acceleration can protect the robot joint action, the optimization index are more often used; optimum energy, which is to reduce energy consumption systems, mainly in the energy constraint strictly limited special occasions, according to the tendency of decision makers prefer to select one or a set of "sufficient satisfaction" Solutions for multi-objective optimization problem as final solution. There are obstacles in the path for the robot trajectory planning, the use of multiple algorithms five robot trajectory planning at the same time the objective function is optimized to achieve optimal trajectory Parent.

V. Conclusions

Aiming serial robots were analyzed by the above-mentioned research can initially draw the optimal configuration for the institution, while adjusting parameters help to improve line speed performance, different sizes have an impact on the overall performance of the robot, by Trend Watch organization dimensional change, provide a theoretical basis for the design of high performance organizations.

Through the study of robot trajectory planning, determine the trajectory of spray painting robots. Lay the foundation for future research.

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