

Welding Trajectory Planning of Beam Welding Robot Based on Computer Simulation

Duan Zhiqun¹, Meng Xiaojing²

¹. Department of Computer Technology, Hebei College of Industry and Technology, Shijiazhuang 050091, P.R.China

². Department of Computer Technology, Hebei College of Industry and Technology, Shijiazhuang 050091, P.R.China

Keywords: robot, trajectory planning, welding

Abstract. When the welding robot receives task instructions, it needs for trajectory planning of welding robot, in order to improve the work efficiency, welding task planning can work from the point of view of the joint space and also it can work from the Cartesian coordinate space planning. This paper analyzes the characteristics of two different planning forms, and gives a specific algorithm of two kinds of programming form. Finally, VECO beam welding robot path planning is taken as an example, and the computer simulation verify the correctness of the form of planning, the algorithm is applied to the IVECO beam welding successfully.

Introduction

According to the different tasks requirements, it needs for the trajectory planning of the robot, the purpose of the trajectory planning of robot can realize the velocity, acceleration running analysis precisely, in order to achieve the purpose of the desired trajectory and to specify the velocity, acceleration running, the trajectory planning is taken, welding task planning can work from the point of view of the joint space and also it can work from the Cartesian coordinate space planning. Based on trajectory planning in joint space, the joint independent processing are planning, speed and acceleration of each joint is analyzed, it has the advantages of small calculation amount, and it has high efficiency and no singular space^[1-3].

Based on trajectory planning in joint space, the joint independent processing are planning, speed and acceleration of each joint, with the advantages of small calculation amount, high efficiency and no singular space. Also, the planning mechanism can divided into on-line and off-line planning, the trajectory planning of the robot is suitable for robot task planning without special requirements on the movement of the intermediate process. The drawback of this approach is unable to predict the middle operation process of curve, the obstacles in the workspace interfere the planning precision, causing the unsafe factors^[4]. The space trajectory planning of robot based on Cartesian coordinates takes the planning processing as a whole, each movement of the joint and Cartesian space associated to the whole process of planning, movement. It often uses the known function of planning, the disadvantage is the large amount of calculation, it is a complex algorithm, and the running time cost a lot, and the velocity and acceleration is shown in uncertainty. This paper introduces the concrete steps of two kinds of planning method, and the welding robot is taken as an example, simulation is taken for test the performance of the algorithm^[5-7].

Path planning algorithm and space coordinate trajectory description

Model construction.

The basic principle is that the trajectory of the robot is built through the joint space variable function, realization method can be expressed as: the robot starting point is assumed as $P_0, P_1, P_2, \dots, P_n$, the movement matrix of robot is computed as ${}^0T_0, {}^0T_1, \dots, {}^0T_n$, each joint variables are $q_0, q_1, q_2, \dots, q_n$ and $\{q(t), \dot{q}(t), \ddot{q}(t)\}$. Space coordinate trajectory is abstracted as a virtual world population genetic model of grid structure, and the working space of the robot as shown in Figure 1.

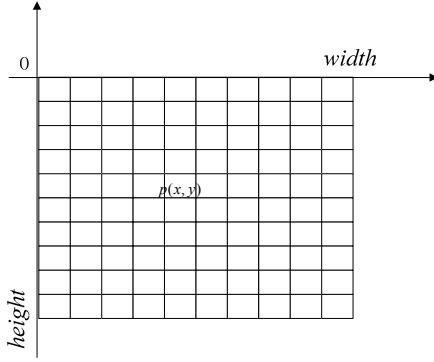


Figure 1. Grid structure model of robot's motion space

In the robot motion space grid structure mode shown in figure 1, the robot motion space can be expressed by a macro and micro organic connection of the plane rectangular coordinate system, the robot path optimization and trajectory tracking control problem can be expressed as multi information fusion decision variables:

$$\begin{aligned} \min \quad & F(x) = (f_1(x), f_2(x), \dots, f_m(x))^T \\ \text{s.t.} \quad & g_i \leq 0, \quad i = 1, 2, \dots, q \\ & h_j = 0, \quad j = 1, 2, \dots, p \end{aligned} \quad (1)$$

The robot is a nonlinear system itself, the linearization processing is need to control equation of the robot, in a small angle range, setting $\sin \theta_p = \theta_p$, $\cos \theta_p = 1$, in the tracking control of robot motion and trajectory planning of welding robot, assumed that $J_{p\delta}$ is the machine body around a vertical axis (Y axis) moment of inertia, the several constraint conditions of robot motion and trajectory planning are expressed as follows:

$$X_{RL} = R \times \theta_{RL} \quad (2)$$

$$X_{RR} = R \times \theta_{RR} \quad (3)$$

$$X_P = X_{RM} + L \sin \theta_P \quad (4)$$

$$\dot{X}_P = \dot{\theta}_P L \cos \theta_P + \dot{X}_{RM} \quad (5)$$

$$Y_P = L \cos \theta_P \quad (6)$$

$$\dot{Y}_P = -\dot{\theta}_P L \sin \theta_P \quad (7)$$

$$X_{RR} + X_{RL} = 2X_{RM} \quad (8)$$

Combined with figure 1, among them, $width \times height$ is the domain of definition of coordinate, because the computer can only deal with the discrete information, so the discrete control system of robot world is nonlinear coupling. As the domain of definition of coordinate, because the computer can only deal with the discrete information, so the discrete control system of robot world is nonlinear coupling, the robot motion can be divided as end PTP motion and process PTP motion.

(1) End PTP motion

Only through the PTP motion movement refers to the robot only considers the starting point and the end pose in the running process, the processing posture can be ignored in the process of movement. Assumed the initial transformation matrix of robots is T_6^0 , and the initial time, ach joint variables are $q_i^0 (i=1, 2, \dots, 6)$, defined that the end position of t_f end time is the transformation matrix of the robot T_6^1 , and the current position, the joint variables are $q_i^1 (i=1, 2, \dots, 6)$, In order to meet the position and pose transformation by two points, the transition function $q_i(t)$ of robot joint can be find out.

(2) PTP motion with the process points

In most application environments, the operation of the robot not only needs to satisfy the posture change from the point of its operation, he process also need to follow the path of the intended, to enable the robot to smoothly reach the predetermined trajectory. Given the initial

position of the robot T_6^0 , and the motion need to go through the process $T_6^1, T_6^2, \dots, T_6^{m-1}$. The final location of the robot end pose is T_6^n , the different positions of the joint variables are expressed as $q_i^0, q_i^1, q_i^2, \dots, q_i^m (i=1,2,\dots,6)$, and the exercise time can be subdivided into t_1, t_2, \dots, t_n .

Cartesian space trajectory planning.

In most cases, the robot's task is a continuous process, the entire process requires the robot to have certain precision. Such as electric arc welding robot, palletizing robot, which in strict accordance with the requirements of the end operator of a predetermined trajectory continuous operation. The design of entering and exiting the stage of the trajectory need to track the overall smoothness. At the same time, in order to avoid the frequent changes of the vibration velocity and acceleration of the impact, and requires the continuity of velocity and acceleration, and it shows as a smooth transition.

Linear trajectory planning.

Given the whole point information of a given robot, and two points determine the line dividing into a plurality of cells, the line planning of kinematics and dynamics is solved for each point, determine the attitude and driving torque.

Given the initial position T_6^0 of the robot, in Cartesian coordinates, the position is $p^0 = (p_x^0, p_y^0, p_z^0)^T$, the rotation is T_0, U_0, V_0 , moving along a straight line to another point position T_6^1 , in the Cartesian coordinate, the position is $p^1 = (p_x^1, p_y^1, p_z^1)^T$, the rotation angle is T_0, U_0, V_0 , the two points is subdivided into n interval, then pose increment in every interval is:

$$\begin{aligned} \Delta x &= (p_x^1 - p_x^0)/n & \Delta T &= (T_1 - T_0)/n \\ \Delta y &= (p_y^1 - p_y^0)/n & \Delta U &= (U_1 - U_0)/n \\ \Delta z &= (p_z^1 - p_z^0)/n & \Delta V &= (V_1 - V_0)/n \end{aligned} \quad (9)$$

According to equation (1), position and angle of each point is obtained by point subdivision $x_i, y_i, z_i, T_i, U_i, V_i (i=1,2,\dots,6)$, all the points of the kinematic and dynamic equations of the robot are divided into segments, and driving torque of each joint of the robot can be obtained, in order to drive the robot motion along a straight line, the end effector motion scheduled can be ensured.

Round or circular arc trajectory planning.

Given the initial position T_6^0 of the robot, in Cartesian coordinates, the position is $p^0 = (p_x^0, p_y^0, p_z^0)^T$, the rotation is T_0, U_0, V_0 , moving along a straight line to another point position T_6^1 , in the Cartesian coordinate, the position is $p^2 = (p_x^2, p_y^2, p_z^2)^T$, the rotation angle is T_2, U_2, V_2 , the two points is subdivided into n interval, The three point circle equation is:

$$(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 = r^2 \quad (10)$$

Simulation and trajectory planning algorithm

Computer simulation of trajectory planning.

According to the classification of the trajectory planning, welding task planning can work from the point of view of the joint space and also it can work from the Cartesian coordinate space planning. This paper analyzes the characteristics of two different planning forms, and gives a specific algorithm of two kinds of programming form. Based on simulation of space trajectory planning in Cartesian coordinates, the trajectory planning is optimized. Consider only the movement of the end effector of a robot task by two attitude, the joint space trajectory planning is optimized based on simulation. Planning principles is used to ensure that the end of the initial point and end point, the process speed can be accelerated, acceleration without frequent shocks, the movement stable transition and other requirements can be obtained.

Space trajectory planning simulation based on Cartesian coordinate.

Not only to consider the end effector of a robot end pose, but also consider the whole process in accordance with the expected trajectory of the robot task set by the speed, acceleration run, need to

use Cartesian space trajectory planning. All joints of robot are described in the Cartesian coordinates. Set the path running time T , and is divided into sections, each section of the inter cell operation time Δt . All the pose information is processed and calculated in the trajectory, kinematics and dynamics equations of the robot, and the desired position, velocity, acceleration and every moment of each joint driven torque are solved.

Flow chart of trajectory planning algorithm.

Flow chart of the algorithm is shown in Figure 2:

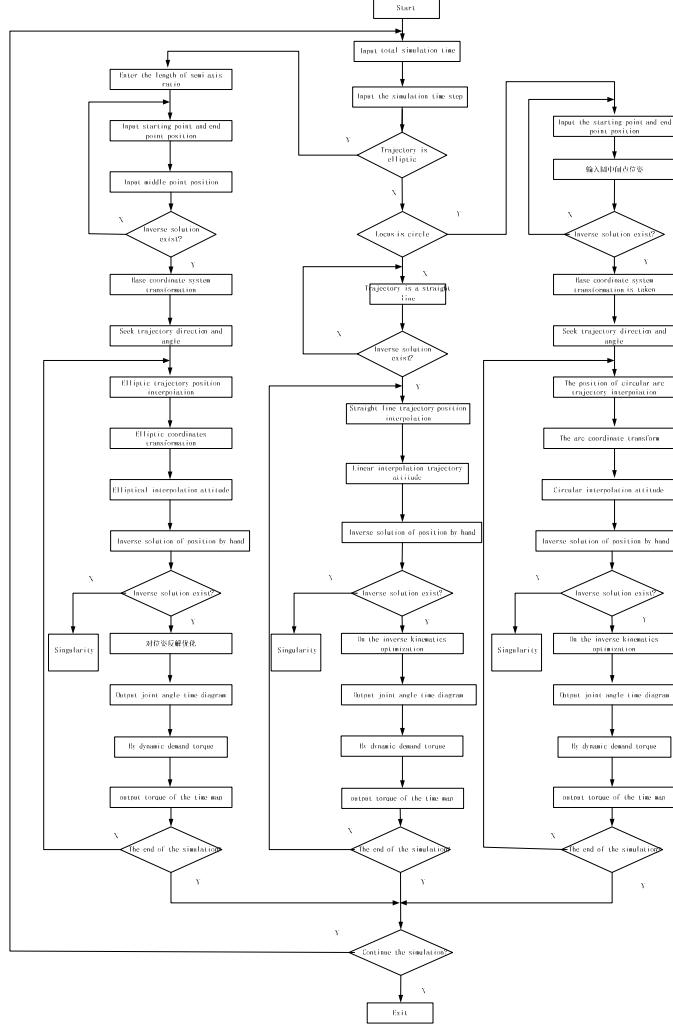


Figure 2 Flow chart of trajectory planning algorithm

Welding of IVECO beams

The IVECO beam is composed of an end cover, beam and frame welding molding, and it is shown in Figure 3. The welding process is divided into two steps, the first step is that the end cover and the inner ring beam welding joint, and the second step is that welding of end cover and the outer ring beam joint and support. A schematic diagram of the welding process is shown in Figure 4. The first step for welding is shown in the bottom left, he beam on the bench all week to complete the welding seam rotating inner ring is covered, the beam on the bench all week to complete the welding seam is rotating inner ring, right for the second step first spot welding bracket, then the outer ring seam welding. Figure 5 shows the beam welding process path planning diagram. According to the task plan to complete the task of welding, the welding path layout is shown in figure 6. The robot end effector is the torch along the following node movement:

$$a \rightarrow b \rightarrow c \rightarrow d \rightarrow e \rightarrow f \rightarrow g \rightarrow hh'h'' \rightarrow i \rightarrow j \rightarrow kk'k'' \rightarrow l \rightarrow mno \rightarrow p \rightarrow qrs \rightarrow t \rightarrow u \rightarrow b$$

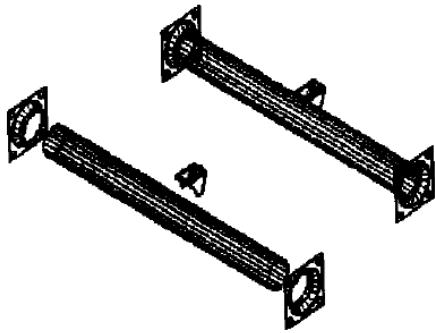


Figure 3 IVECO beam map

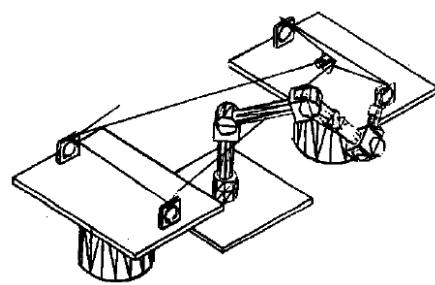


Figure 4 IVECO beam welding location map

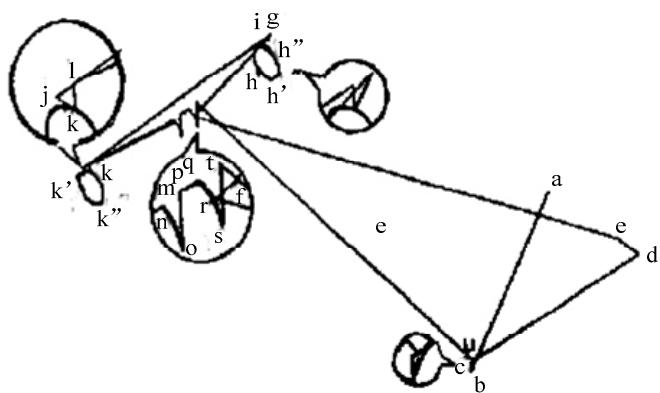


Figure 5. IVECO beam welding path diagram

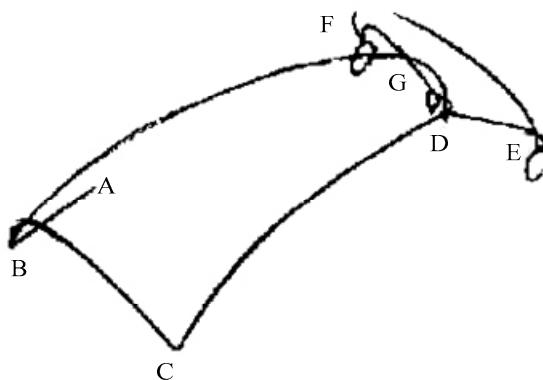


Figure 6. Welding trajectory planning in Cartesian coordinate system

Conclusions

In this paper, a detailed analysis of the joint space trajectory planning and planning is researched based on the basic principle of two kinds of algorithm in Cartesian trajectory. The welding task planning can work from the point of view of the joint space and also it can work from the Cartesian coordinate space planning. This paper analyzes the characteristics of two different planning forms, and gives a specific algorithm of two kinds of programming form. Finally, VECO beam welding robot path planning is taken as an example, and the computer simulation verify the correctness of the form of planning. Finally, based on IVECO beam welding as an example, the welding task is divided into multiple interval, the trajectory planning of the line and arc interpolation transition to complete the welding task, the algorithm is applied to the IVECO beam welding successfully. It has good application value in practice.

References

- [1] GE Lizhi. Visual simulation of UUV Attack Model Based on Whole Trajectory Control Analysis[J]. Ship Electrolic Engineering, 2015,35(3):137-141.
- [2] WANG Ming, HUANG Panfeng, CHANG Haitao etc. Coordinated Attitude Control of Combined Spacecraft Based on Estimated Coupling Torque of Manipulator[J]. ROBOT, 2015,37(1): 25-34.
- [3] ZHANG Han, CHEN Weidong, WANG Jingchuan. Human-Robot Shared Control for Multi-Robot Exploration System[J]. ROBOT, 2015,37(1): 17-24.
- [4] Yuan J, Huang Y L, Tong T, et al. A cooperative approach for multi-robot area exploration[C]//IEEE/RSJ International Conference on Intelligent Robots and Systems. Piscataway, USA: IEEE, 2010: 1390-1395.
- [5] KONG Xiangdong, YU Bin, QUAN Lingxiao etc. Characteristic Parameters Sensitivity of Position Servo Control for Hydraulic Drive Unit of a Quadruped Robot in Trotting Gait[J]. ROBOT, 2015,37(1): 63-73.
- [6] PENG Li-ying. Traffic Data Anti Step Fusion Algorithm Based on Improved Sliding Mode Disturbance Control Rule[J]. Control Engineering of China, 2014,21(4): 515-519.
- [7] Wang J Z, Wang S K, et al. Strategy of foot trajectory generation for hydraulic quadruped robots gait planning[J]. Journal of Mechanical Engineering, 2013, 49(1): 39-44.