

Trajectory Planning of the live-line maintenance robot manipulator

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Abstract. Many countries are conducting research on the live-line maintenance robots. Trajectory plan of the manipulator is introduced. Propose a method of trajectory plan. Using Cubic polynomial interpolation algorithm, the joint angle solved by inverse solution can be determined by plan_ algorithm, and the plan curves are achieved.

Introduction

With the society's development, the demand for the stable power supply is more and more stringent and outage-free maintenance is more and more frequent. Despite many methods to enhance the safety of outage-free maintenance are applied, it is still dangerous to touch the line directly. Because of the importance of safety, many countries are conducting research on the live-line maintenance robots. In 1984, the TOKYO electric company cooperated with TOSHIBA FUJI, FURUKAWA electrical company, FUJIKURA electrical company and AICHI electric company to begin to take the live-line maintenance robot in high sky and high voltage to the work of the research and development[1,2,3,4,5]. In other countries such as CANADA, the United States, FRANCEE and SPAIN, the live-line maintenance robot are also introduced to work in the early 1980s.

In China, the power supply bureau have strong requirement of the live-line maintenance robot. As the price of the imported foreign robot is too high, some power bureau hoped to cooperate with universities and colleges, scientific research units to develop independent intellectual property rights live-line maintenance robot. The ChangSha power bureau and the national university of defense technology proposed city high voltage distribution charged to the feasibility study report homework robot in 1991 .In 1992,Anshan power bureau and Shenyang institute of automation Chinese academy of sciences proposed the project report of the live-line maintenance robot in 10kv distribution line.

Manipulator is the part of the live-line maintenance robot. The control issues are two problems that the Trajectory planning and movement control. To complete some operation work, the path must be planned in the robot system. The Trajectory planning is stochastic important problem in the robot system. In the paper, the Trajectory planning of the live-line maintenance robot is researched.

Trajectory Planning algorithms of Manipulator

Robot Trajectory Planning is lower planning and doesn't been involved by Artificial Intelligence problem. The trajectory Planning is in Joint space and Cartesian space, but the trajectory function must be smooth, continuous and operation of the movement of arms. In the paper, the trajectory Plan in Cartesian space is researched.

The motion node of Manipulator is expressed by the position and orientation of the tool coordinate system relate to the job coordinate system. To acquire the trajectory in the joint, first the motion node is transferred to the angle value of joint by inverse resolve of Manipulator; then a smooth function of every joint is fitted curve to make start from starting point to end point and pass through all nodes. The running time of every joint is same in the same motion track. It ensures that all joint arrive the motion node and end point at the same time.

When the joint is interpolated computed, the constraint condition must be conformed to. The displacement, velocity and acceleration of the joint in the running track must be continuous and the extreme value must be in the tolerance range. The different type interpolation algorithms of Joint are selected to process the different track by conform to the according constraint condition. The interpolation algorithms of Joint trajectory are too much and the cubic polynomial interpolation algorithms are discussed.

In the motion of Manipulator, the start point angle θ_0 is known, the endpoint angle θ_f is solved by the kinematics inverse resolve. The track function $\theta(t)$ is expressed by the smooth interpolation function about the start point joint angle and end point joint angel. At $t = 0$, the value of $\theta(t)$ is the value θ_0 of the start point joint angle. At the time of end point t_f , the value of $\theta(t)$ is the value θ_f of the end point joint angle. Obviously, many smooth functions are used as joint interpolation function.

To achieve the smooth movement of the single joint, the track function is conformed to 4 constraint conditions at least, the two of which is the joint angle of the start point and the end point, as shown $\theta(0) = \theta_0, \theta(t_f) = \theta_f$. To satisfy with the continuity of the joint velocity, the others two constraint conditions is the joint velocity of the start point and the end point, as shown $\dot{\theta}(0) = 0, \dot{\theta}(t_f) = 0$. The four constraint conditions ensure a Cubic polynomial one and only, as shown in formula 1.

$$\theta(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \quad (1)$$

The joint velocity and acceleration in the motion track is

$$\left. \begin{aligned} \dot{\theta}(t) &= a_1 + 2a_2 t + 3a_3 t^2 \\ \ddot{\theta}(t) &= 2a_2 + 6a_3 t \end{aligned} \right\} \quad (2)$$

Make formula 1 and 2 into the corresponding constraints, the four linear equations about a_0, a_1, a_2 and a_3 is acquire, as shown in formula3.

$$\left. \begin{aligned} \theta_0 &= a_0 \\ \theta_f &= a_0 + a_1 t_f + a_2 t_f^2 + a_3 t_f^3 \\ 0 &= a_1 \\ 0 &= a_1 + 2a_2 t_f + 3a_3 t_f^2 \end{aligned} \right\} \quad (3)$$

Solve equations set, acquire formula 4.

$$\left. \begin{aligned} a_0 &= \theta_0 \\ a_1 &= 0 \\ a_2 &= \frac{3}{t_f^2}(\theta_f - \theta_0) \\ a_3 &= -\frac{2}{t_f^3}(\theta_f - \theta_0) \end{aligned} \right\} \quad (4)$$

The joint velocity of the track node is set according to demand., the method of set the Cubic polynomial interpolation algorithms is same as the previous formula and only the velocity constraint conditions transfer as: $\dot{\theta}(0) = \dot{\theta}_0, \dot{\theta}(t_f) = \dot{\theta}_f$. The four equations that define the Cubic polynomial is showed as formula5.

$$\left. \begin{aligned} \theta_0 &= a_0 \\ \theta_f &= a_0 + a_1 t_f + a_2 t_f^2 + a_3 t_f^3 \\ \dot{\theta}_0 &= a_1 \\ \dot{\theta}_f &= a_1 + 2a_2 t_f + 3a_3 t_f^2 \end{aligned} \right\} \quad (5)$$

Solve the equations sets (5) and acquire the coefficient of the Cubic polynomial. as shown in formula 6.

$$\left. \begin{aligned} a_0 &= \theta_0 \\ a_1 &= \dot{\theta}_0 \\ a_2 &= \frac{3}{t_f^2}(\theta_f - \theta_0) - \frac{2}{t_f}\dot{\theta}_0 - \frac{1}{t_f}\dot{\theta}_f \\ a_3 &= -\frac{2}{t_f^3}(\theta_f - \theta_0) + \frac{1}{t_f^2}(\dot{\theta}_0 + \dot{\theta}_f) \end{aligned} \right\} \quad (6)$$

The Cubic polynomial that is defined and describes the motion track that the start point and end point velocity is arbitrary.

Trajectory planning of the live-line maintenance robot manipulator

The D-H parameter table of the live-line maintenance robot manipulator and the angle value of every joint is as shown table1. The realized step of Trajectory Planning is as shown:

Table 1 D-H parameter

joint	Coor-dinate	Start value	θ_i	α_i	d_i (mm)	a_i (mm)	Motion range
1	0	90	θ_1	90	0	0	± 180
2	1	90	θ_2	-90	215	0	± 180
3	2	0	θ_3	0	0	550	-45 ~180
4	3	-90	θ_4	-90	0	144	-178 ~145
5	4	0	θ_5	90	540	0	± 180
6	5	0	θ_6	-90	0	0	± 135
7	6	0	θ_7	0	200	0	± 180

Select interpolation algorithms

In fact, the velocity of the track node isn't zero, so the Cubic polynomial interpolation algorithms passing through the track node is selected.

Compute the interpolation function

(1) Select the velocity of track node. Ensure the velocity of track node by inverse resolve according to transient velocity in the tool coordinate system.

(2) Compute interpolation

In figure1, x, y, z express the position of manipulator terminator, the unit is mm. x -coordinate is time unit. In figure2, x_i expresses the angle of the manipulator θ_i , x -coordinate is time unit.

Trajectory Real-time generation

The flow diagram of Trajectory Real-time generation is as shown figure3. Δt is refresh frequency of Trajectory, t_d is the time of Trajectory end point.

Summary

In the paper, the Cubic polynomial interpolation algorithms passing through the track node is selected to compute the Trajectory planning of the live-line maintenance robot manipulator in fact. The paper completes the Trajectory planning and simulates it.

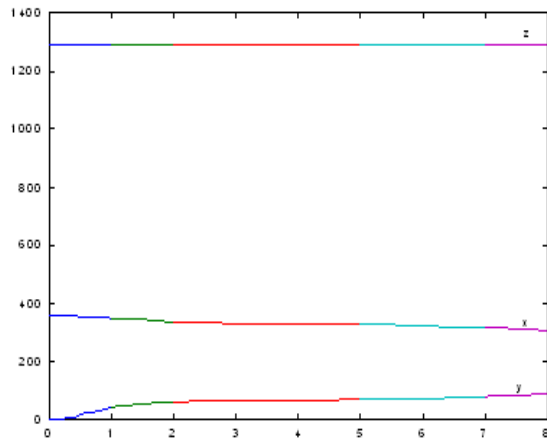


Fig 1 the position of manipulator terminator

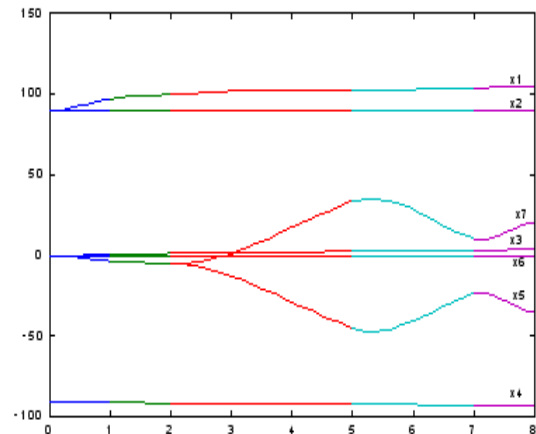


Fig 2 the curve of the joint angel

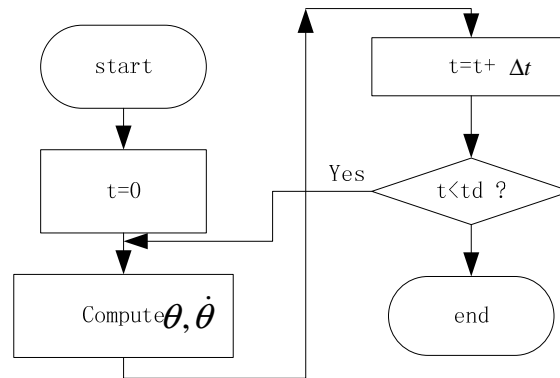


Fig 3 The flow diagram of Trajectory generation

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