Trajectory planning of lower limb exoskeleton robot

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Abstract

With the increasing aging of China's population, the problem of the elderly quickly became one of the national concerns.Comes with an ageing population, diseases of aging, the body rheumatism and arthritis cause more old people limp and lower limbs, the condition of invariable, therefore man handicapped people would also become more and more patients with lower limb paralysis or motor dysfunction in the field of medical rehabilitation training also needs to support the mechanical device, protection and power.[1] in view of the current situation, various scientific research institutes in China have invested in the direction of solving this problem.In addition, certain achievements have been made. A lower limb exoskeleton robot has been developed to assist the walking of disabled people, and remarkable achievements have been made in the aspects of driving mode, control mode, and trajectory planning, etc., which is very beneficial to the further research and development of lower limb exoskeleton robot.

Keywords

Lower limb exoskeleton robot, control mode, trajectory planning.

1. Introduction

With the continuous development of industrial automation in the 21st century, a lot of manual work in the field of industrial production was replaced with industrial robots, industrial robots, with its precision, flexibility and high efficiency, greatly improve the labor productivity, reduce the burden of workers, and even can perform many human cannot execute complex work type joint industrial robot, with its good flexibility and high efficient working mode is widely used in modern industrial automation production, such as handling, stacking, welding, cutting, etc.Trajectory planning is a basic research field of industrial robot motion control, which determines its operational efficiency and motion performance.The quality of the track planning scheme is high or lowIt determines the movement mode, operation accuracy and service life of the robot. A good trajectory planning scheme can not only enable the robot to complete the task accurately, but also ensure good motion stability and less mechanical wear.You will also do well in terms of time use and energy expenditure.

2. Lower limb exoskeleton structural design

According to the basic data of the size of human standing provided by the Chinese adult human body size [1], the proportion of 175mm of human body designed the basic size of the lower limb exoskeleton robot as follows: hip size 335mm, thigh size 426mm, shank size 425mm and feet size 66mm.The degrees of freedom of each joint of human lower limb: the hip joint is 3 degrees of freedom, respectively, including adduction/extension, flexion/extension, and pronation/ extension; The knee joint is one degree of freedom and is flexion/extension;The ankle joint is three degrees of freedom, whichareintroversion/eversion,dorsalflexion/toeflexion and pronation/ pronation. Motor drive is adopted to design the lower limb exoskeleton robot. The motor drive mode is quick and sensitive, which basically conforms to the motion state of human lower limb exoskeleton.

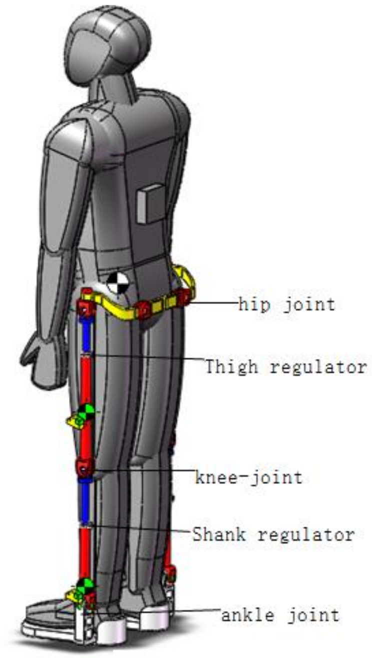

Fig .1 Mechanical model of human lower limb exoskeleton

3. Path planning

The trajectory refers to the time course of the position, velocity, and acceleration of each degree of freedom.Trajectory planning the curved trajectory of the end of the mechanical arm, or the curve contour of the displacement, velocity, and acceleration of the operating arm during motion.In most cases, the motion of the manipulator is regarded as the motion of the tool coordinate system relative to the workbench coordinate system.The task of moving the robot shown from the initial state to the termination state is regarded as the coordinate transformation of tool coordinate system from the initial position {T0} to the final position {Tf}.

Trajectory is divided into two types: fixed-point operation and curved surface machining.For a fixed point, you only need to describe the state of the starting point and the ending point.Another is to indicate the intermediate point (the transition point between the initial position and the final expectation) and move along a particular path.

In planning the robot trajectory, it is also necessary to determine whether there are obstacles in the path，FIG. 2 movement of mechanical arm

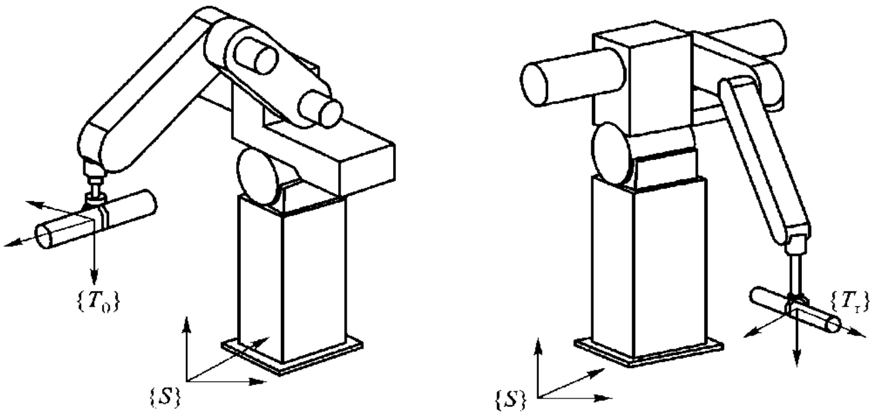

Fig. 2 movement of mechanical arm

The motion of the manipulator should be smooth, the sharp motion will aggravate the wear of the mechanism and cause the vibration of the manipulator to choose the motion trajectory description function must be continuous, and its first derivative (velocity), sometimes second derivative (acceleration) should also be continuous.

Trajectory planning can be done in joint space or rectangular coordinate space.In joint space planning, the joint variable is expressed as a function of time and its first and second time derivatives are planned.Planning in rectangular space is a function of time to represent the posture, velocity and acceleration of the hand.The corresponding joint displacement, velocity and acceleration are derived from the information of the hand.Usually joint displacement is obtained by inverse kinematics, joint velocity is obtained by inverse jacobian, and joint acceleration is solved by inverse jacobian and its derivative.

4. Trajectory planning is divided into joint space method and cartesian space planning method

the joint space method is a function of joint Angle to describe the trajectory of the robot. The joint space method does not have to describe the path shape between two path points in rectangular coordinate system. The calculation is simple and easy.Furthermore, as the joint space is not in continuous correspondence with the rectangular coordinate space, the singularity of the mechanism does not occur.Method of difference in joint trajectory planning: 1. Interpolation of cubic polynomial; 2.2. Interpolation of cubic polynomials over path points;3. Interpolation of higher order polynomials;4. Linear interpolation with parabolic transition;5. Linear interpolation through parabolic transitionsof path points.

4.1 Difference of cubic polynomial:

Only the joint angles of the starting and ending points of the robot are given， As shown in figure 3.

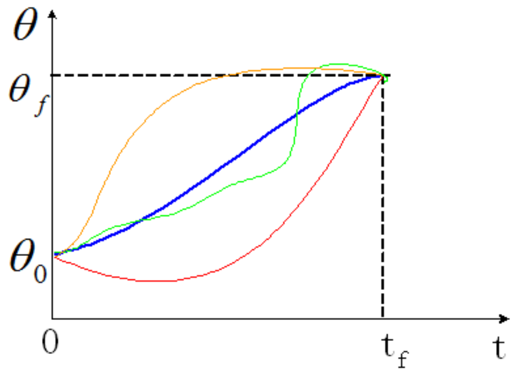

Fig .4 Joint Angle diagram of the robot's starting point and ending point

$$\theta\left(t\right) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$

n order to obtain a certain smooth trajectory, at least four constraints are applied.

1. Initial value:;

2 final value:;

Joint velocity is zero at the initial and final time:;

Solution of: , $a_1 = 0$, $a_2 = \frac{3}{t_f^2}\left(\theta_f = \theta_0\right)$, $a_3 = -\frac{2}{t_f^3}\left(\theta_f - \theta_0\right)$;

Rearrange the original equation:

$$\theta(t) = \theta_0 + \frac{3}{t_f^2}(\theta_f - \theta_0)t^2 + \frac{2}{t_f^3}(\theta_f - \theta_0)t^3$$

4.2 A tertiary polynomial having a path of intermediate points

The two adjacent path points on each joint are respectively regarded as the starting point and the ending point, and then the corresponding cubic polynomial interpolation function is determined to connect the path points smoothly.In general, the joint velocity at these starting and ending points is no longer zero. FIG. 4 the velocity at the start and end points

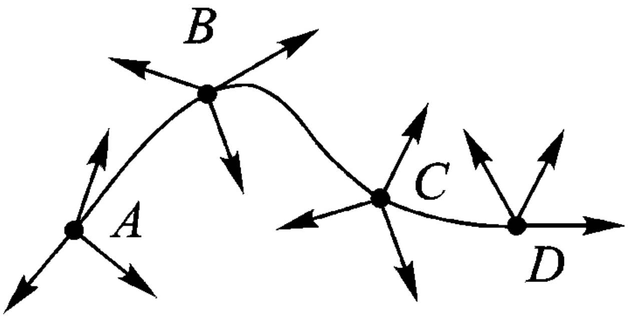

Fig. 4 the velocity at the start and end points

The constraint becomes: $\dot{\theta}(0)=\dot{\theta}_0$, $\dot{\theta}(t_f)=\dot{\theta}_f$;

$$a_0=\theta_0$$

$$a_1=\dot{\theta}_0$$

Solution of: $a_2=\frac{3}{t_f^2}(\theta_f-\theta_0)-\frac{2}{t_f}\dot{\theta}_0-\frac{1}{t_f}\dot{\theta}_f$

$$a_3=\frac{2}{t_f^3}(\theta_f-\theta_0)+\frac{1}{t_f^2}(\dot{\theta}_0+\dot{\theta}_f)$$

4.3 Higher order polynomial

General path segments use higher order polynomials.To determine the position, velocity, and acceleration of the starting and ending points, a five-degree polynomial difference is required.

$$\theta(t)=a_0+a_1t+a_2t^2+a_3t^3+a_4t^4+a_5t^5$$

$$\dot{\theta}(t)=a_1+2a_2t\ +3a_3t^2+4a_4t^3+5a_5t^4$$

$$\ddot{\theta}(t)=2a_2+6a_3t+12a_4t^2+20a_5t^3$$

According to these equations, the coefficients of the fifth degree polynomial can be calculated through the constraints of position, velocity and acceleration.

4.4 A linear function fitted with a parabola

Simple linear interpolation will result in discontinuous motion and infinite acceleration at the junction. FIG. 5 time and Angle curves.

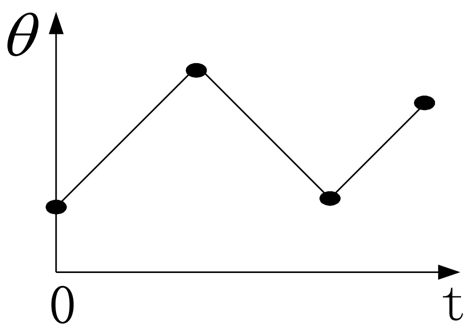

Fig. 5 time and Angle curves.

Solution: As shown in figure 6a smooth trajectory with continuous position and speed is first performed by linear function, and a parabolic fitting region is added to each path point.

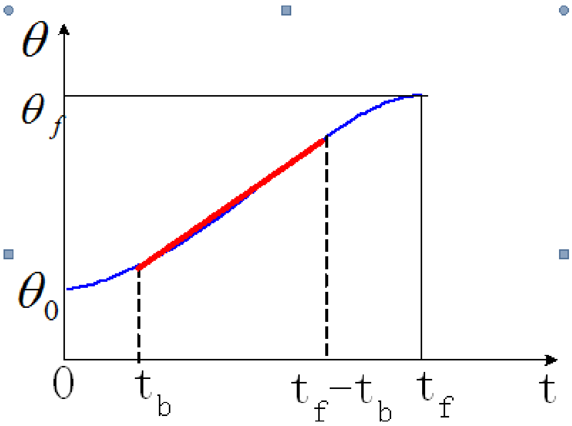

Fig.6 Linear interpolation with parabolic transitions

For the multi-solution case, the figure below shows.The larger the acceleration, the shorter the transition. Figure 7 linear interpolation with parabolic transitions

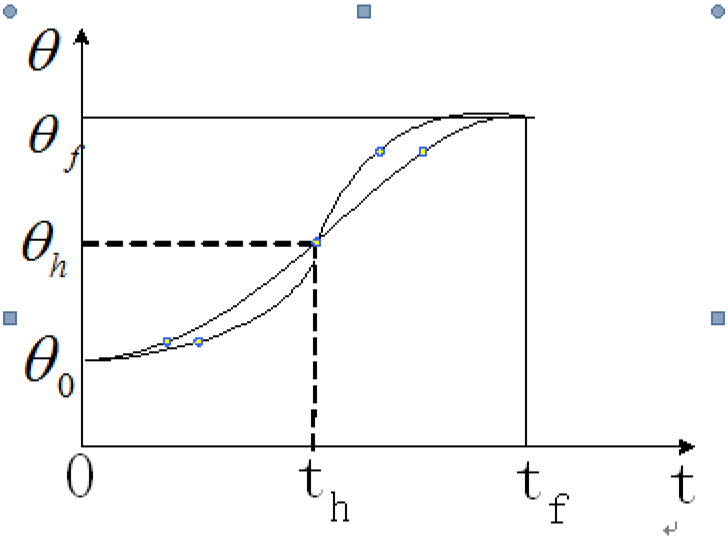

Fig. 7 Linear interpolation with parabolic transitions

4.5 A linear function having the path of an intermediate point fitted to a parabola

As shown in the figure, a certain joint has n path points in its motion, among which three adjacent path points are j, k and l, and each two adjacent path points are connected by a linear function, while there is a parabolic transition near all path points.(there are also multiple solutions) igure 8 shows the linear interpolation trajectory with parabolic transitions in multiple segments.

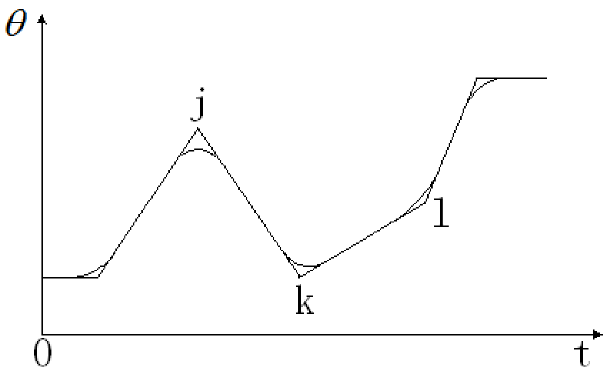

Fig. 8 shows the linear interpolation trajectory with parabolic transitions in multiple segments cartesian space trajectory planning method：Cartesian space is also called task space, which is the working space of robot end-effector.Common DescartesSpace trajectory planning is generally divided into linear planning, circular arc planning, polynomial curve planning, spline curve planning and "S" velocity curve planning.The linear trajectory planning is generally obtained by the normalized linear equidistant or equal time interpolation, and its interpolation algorithm is as follows:

$$\begin{cases} x = x_0 + \lambda(x_n - x_0) \\ y = y_0 + \lambda(y_n - y_0) \\ z = z_0 + \lambda(z_n - z_0) \\ \alpha = \alpha_0 + \lambda(\alpha_n - \alpha_0) \\ \beta = \beta_0 + \lambda(\beta_n - \beta_0) \\ \gamma = \gamma_0 + \lambda(\gamma_n - \gamma_0) \end{cases}$$

Arc trajectory planning is generally divided into plane arc interpolation and space arc interpolation, when interpolation is required to know the arc through the three intermediate points.Planar circular interpolation is generally obtained by normalizing equal time or equal Angle interpolation in spaceIn general, the interpolation problem of circular arc can be transformed to plane through spatial change, and then planar circular interpolation can be carried out, as shown in figure 9

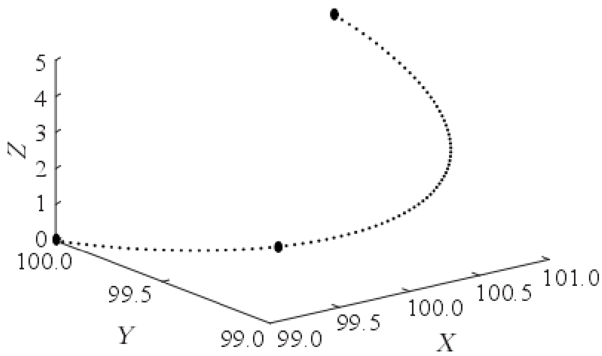

Fig. 9 arc interpolation

Industrial robot path planning in the robot's motion control occupies the important position, not only directly to guide the robot end executor works, but also to the robot's movement efficiency, energy consumption, smooth running and service life has a great influence, so the trajectory planning also became nowadays machine form one of the most important research field.

5. Conclusion

This paper mainly USES the simulation modeling of the lower limb exoskeleton robot to analyze the gait planning of human walking. It analyzes the gait route of the robot and the planning path in the walking process from the theoretical perspective, providing theoretical basis and guarantee for the actual walking of the lower limb exoskeleton robot.

References

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