Research on the position solution and workspace of the kinematics of the terminal actuator of the knee joint robot

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Abstract

The kinematics of the robot is the basis for the study of the robot. The positive and inverse solution of the moving position of a robot lays a foundation for the study of the motion characteristics of the robot. Under the selection of the whole reference coordinates of the robot, the position of the terminal actuator in the reference coordinate system is obtained by the vector change according to the reference coordinates. When the terminal actuator coordinates of the robot are known, the changes of the joints are deduced in reverse. This is the inverse solution of the robot's position. The Monte Carlo method is used to find the workspace of the robot to see if it meets the needs of the actual work.

Keywords

Positive solution of position,Inverse position solution,Monte Carlo method.

1. Introduction

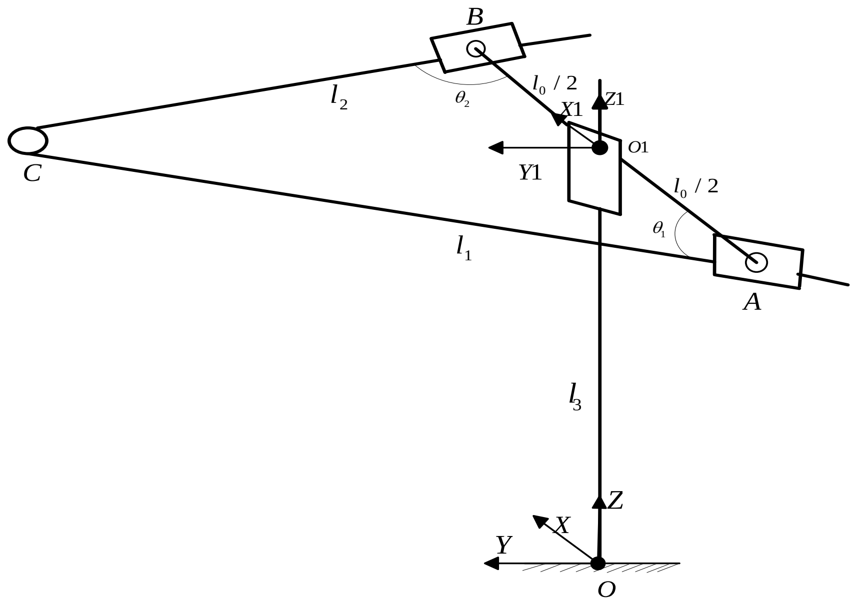


Fig.1 Schematic diagram of robot structure

A knee joint grinding robot is a three degree of freedom robot,It uses a cylindrical coordinate system. Select the $O(x, y, z)$ point as the reference point of the fixed coordinate system. The robot is a degree of freedom in a vertical mechanism, and two mechanical arms are connected in parallel to form 2 degrees of freedom[1]. The common methods for robot kinematics are coordinate transformation and vector method. The kinematics of the robot is related to the fixed coordinate system and the geometric relationship analysis. Monte Carlo method is a common method to study the workspace of robot, which provides a theoretical basis for the actual design of robots.

2. Kinematics of a knee joint grinding robot

2.1 Positive solution of robot position

The positive solution of the position of the robot for the knee joint grinding is to find the motion of each member, and to solve the position of the end actuators in the fixed coordinate system.

Known l_1, l_2, l_3,to find the coordinates of the end point $C(x_c, y_c, z_c)$.

The parallel part of the knee joint grinding robot is a special triangle, so there are the following constraints[2]:

$$\begin{cases} (x_c+\dfrac{l_0}{2})^2+{y_c}^2={l_1}^2 \\ (x_c-\dfrac{l_0}{2})^2+{y_c}^2={l_2}^2 \end{cases} \tag{1}$$

The positive solution of the kinematic position of the robot can be obtained from the fornt formula.

$$\begin{cases} x_c=\dfrac{l_1^2-l_2^2}{2l_0} \\ y_c=\sqrt{\dfrac{l_1^2}{2}-\dfrac{l_0^2}{4}+\dfrac{l_2^2}{2}-\dfrac{(l_1^2-l_2^2)^2}{4l_0^2}} \\ z_C=z_{O1}=l_3 \end{cases} \tag{2}$$

2.2 Inverse position solution of robot position

The coordinates of the end executor in the fixed coordinate system are $C(x_c, y_c, z_c)$. The equation of the vector can be obtained[3]:

$$\overrightarrow{OO_1}+\overrightarrow{O_1A}+\overrightarrow{AC}=\overrightarrow{OO_1}+\overrightarrow{O_1B}+\overrightarrow{BC}$$

$\overrightarrow{OO_1}+\overrightarrow{O_1A}+\overrightarrow{AC}=\overrightarrow{O_1C}$, to get C point coordinates

$$\begin{cases} x_c=-\dfrac{l_0}{2}+\cos\theta_1\cdot l_1 \\ y_c=\sin\theta_1\cdot l_1 \\ z_C=\mathrm{z}_{O1}=l_3 \end{cases} \tag{3}$$

Similarly, $\overrightarrow{OO_1}+\overrightarrow{O_1B}+\overrightarrow{BC}=\overrightarrow{O_1C}$, to get C point coordinates

$$\begin{cases} x_c=\dfrac{l_0}{2}-\cos\theta_2\cdot l_2 \\ y_c=\sin\theta_2\cdot l_2 \\ z_C=z_{O1}=l_3 \end{cases} \tag{4}$$

To deal with the formula (3) as follows：

$${x_c}^2+{y_c}^2=\cos^2\theta_1\cdot {l_1}^2+\sin^2\theta_1\cdot {l_1}^2+{l_0}^2/4-l_0\cdot l_1\cos\theta_1 \tag{5}$$

Get the following formula:

$$\cos\theta_1 = \frac{l_0/2 + x_c}{l_1} \tag{6}$$

To bring (3) to (5) can be obtained:

$$l_1 = \sqrt{x_c^{\ 2} + y_c^{\ 2} + \frac{l_0^{\ 2}}{4} + l_0 \cdot x_c} \tag{7}$$

The same method can be used:

$$l_2 = \sqrt{x_c^{\ 2} + y_c^{\ 2} + \frac{l_0^2}{4} - l_0 \cdot x_c} \tag{8}$$

The inverse kinematics of the kinematic position is the change of the motion of each moving bar[4].

$$\begin{cases} \Delta l_1 = \sqrt{x_c^{\ 2} + y_c^{\ 2} + \frac{l_0^2}{4} + l_0 \cdot x_c} - l_1^{'} \\ \Delta l_2 = \sqrt{x_c^{\ 2} + y_c^{\ 2} + \frac{l_0^2}{4} - l_0 \cdot x_c} - l_2^{'} \\ \Delta l_3 = z_c - l_3^{'} \end{cases} \tag{9}$$

In this formula: $l_1^{'}$, $l_2^{'}$, $l_3^{'}$ are the length of the initial position of the rod.

3. Simulation workspace

The method of Monte Carlo is a widely used to solve robot workspace at present. The idea is to combine the random interaction of generalized joint variables by probability random sampling and The workspace is solved by computer imulation.

The principle is that[5]:

$$W = \{\omega(q) : q \in Q\} \subset R^3 \tag{10}$$

In the formula, W - is the workspace of the robot terminal executor; q - is a generalized joint variable of a robot; $\omega(q)$ - is a generalized joint variable function of a robot; Q - is the joint space of a joint grinding robot; R^3 - is a simulated workspace.

The generalized joint variables are randomly defined as[6]:

$$q_i = q_i^{\min} + (q_i^{\max} - q_i^{\min}) \times Rand(N,1) \tag{11}$$

The random variable representation of a robot's generalized joint:

$$q_i^{\min} \le q_i \le q_i^{\max}, (i = 1,2,3......n) \tag{12}$$

In the formula, $q_i^{\min}$ -is the minimum value of joint variable; $q_i^{\max}$ -is the maximum value of joint variable.

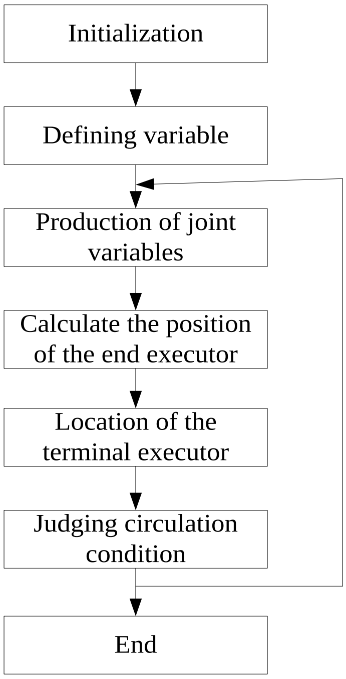
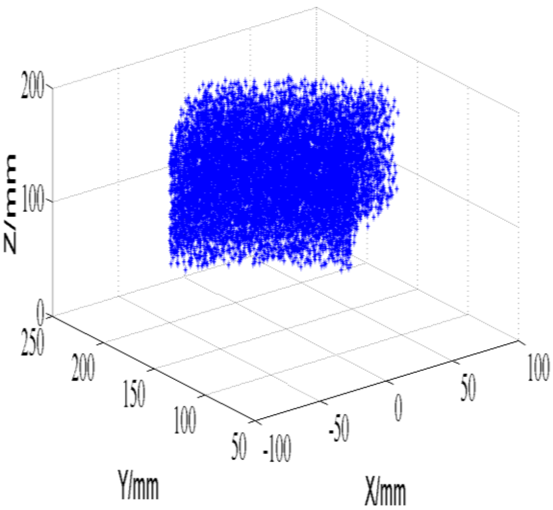


Fig.2.The Monte Carlo method takes the following flow chart:

Finally, the workspace simulation of a knee joint grinding robot is obtained:



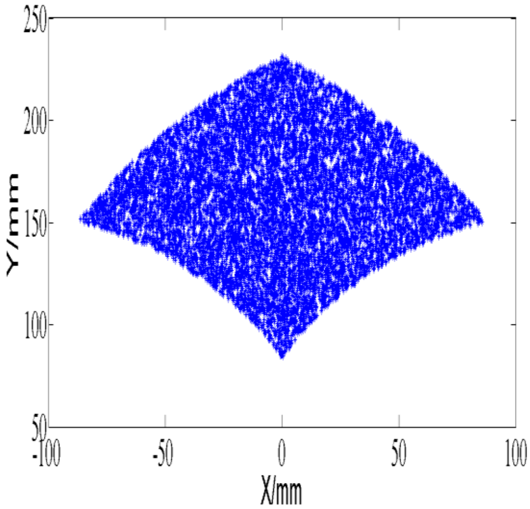
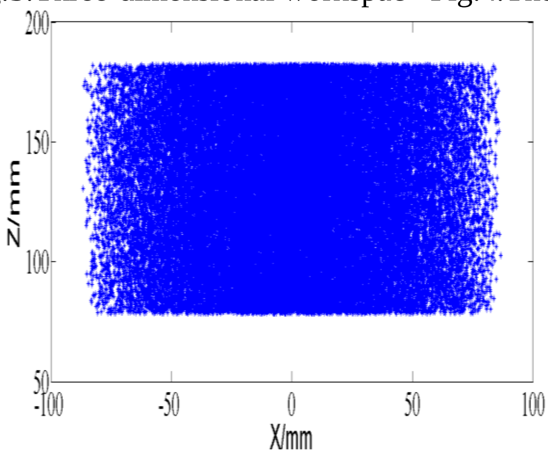


Fig.3.Three-dimensional workspac Fig.4.The projection of the workspace on the XY axis



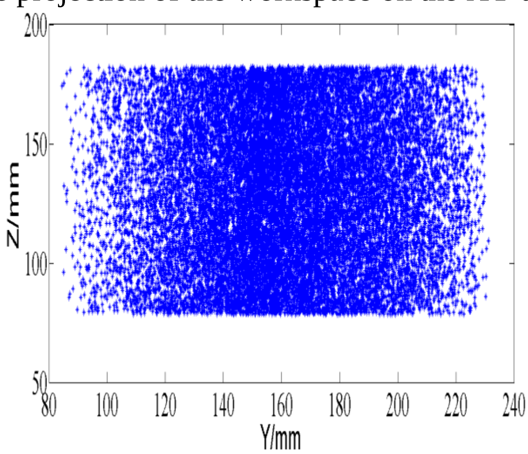


Fig.5.The projection of the workspace on the XZ axis Fig.6.The projection of the workspace on the ZY axis

The workspace shown in the Monte Carlo method shows that the constraints are limited by the length of the rod : $157 \le l_1 \le 267$, $157 \le l_2 \le 267$, $78 \le l_3 \le 182$.

So, space is probably a cylindrical space; The scope of the working space in the fixed coordinate system $O(x, \mathrm{y}, \mathrm{z})$ can be seen $-80 \le x \le 80$, $80 \le y \le 240$, $80 \le z \le 180$ .The workspace is sufficient for the grinding of the knee joint.

4. Conclusion and Future Work

Using the space vector method to get the position of the robot terminal in the fixed coordinate system. Through the inverse solution of the robot's position, the change of the end position in each member is obtained. The working range of the robot terminal executor is obtained by Monte Carlo method. In reference to the range of the knee joint, it is suitable for the operation of the knee joint grinding. The forward and inverse solution and workspace simulation of the joint grinding robot are studied, which lays the foundation for the study of the motion characteristics and dynamics of the robot in the future.

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