The research of rapid construction method for kinematics coordinate system during the graduate course

Mengjun Song

School of Automobile and Transportation, Tianjin university of technology and education, Tianjin 300222, China

Abstract. In the graduate education, the kinematics research for the serial or even the parallel mechanism is always difficult for mastering by using the DH rule, though the rule is presented for years. In order to study how to solve the serial robot kinematics quickly, so we transformed the kinematics coordinate system by different coordinate axes, and the computed results show that transforming the kinematics coordinate system by different axes could solve the kinematic model quickly and efficiently.

Keywords: Graduate education; DH rule; Kinematics; Education method.

1. Introduction

For the graduate student, the traditional curriculum for constructing system of the open mechanism kinematics model of the serial robot is to solve the coordinate transformations of the kinematic equations by using DH rule[1], while, this method has been usually proved to be less efficient and difficult to image during the transforming process for the graduate student cognizing the first time, especially in constructing some complex kinematic mechanisms, the analysis processes usually not easy to execute. So, in this paper, new and easy learning method is presented for constructing the kinematic model of serial robot more quickly.

2. Constructing the kinematic model by using DH rule

In fig.1, the joints distributed condition of one serial robot are showed. In order to study the motion ability of the serial robot, researcher usually solve the mathematical relation between different joints using the DH rule, and the DH rule is proposed by Denavit-Hartenberg in 1955.

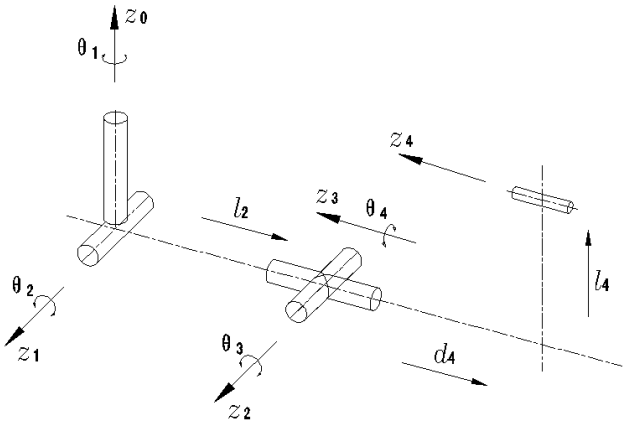


Fig.1 kinematic model of serial robot

In DH rule, there are four different DH parameters, namely link length (l_i), twist angle(a_i), joint offset (d_i), and joint angle (θ_i), required to completely describe the robotic mechanism especially the serial mechanism. Furthermore, all the DH parameters are obtained by considering only X or Z axis as the rotation or translation axis. So we can get the final result as shown in table 1:

Table 1 DH parameters of the serial robot

Link n	θ_n	d_n	a_n	α_n
1	θ_1	0	0	90 °
2	θ_2	0	l_2	0
3	θ_3	0	0	-90 °
4	θ_4	-d_4	l_4	-90 °

In order to solve the whole serial mechanism of the robot discussed above, another important kinematic equation must be calculated firstly, as shown in Eq. (1):

$$^{0}A_{1} = Rot(z,\theta_1)Trans(0,0,d_1)Trans(a_1,0,0)Rot(x,a_1) \quad (1)$$

And the Eq. (1) could be solved by using the data listed on line 2 of table 1. By using the method above, the whole transformation process of the kinematic model could be solved by Eq. (2)

$$^{0}T_{4} = {}^{0}A_{1}\,{}^{0}A_{2}\,{}^{0}A_{3}\,{}^{0}A_{4} \quad (2)$$

We could get the whole kinematic equation of the mechanism shown in Fig. (a) As shown in table.2:

Table 2 posture solution of the kinematic model

x	posture	y	posture	z	postrue	P	postion
nx	-c1s23 c5+s1s5	ox	c1s23s5+s1c5	ax	c1 c23	px	-c1s23c5l5- s1s5l5+ c1 c23d4+c1c2 l2
ny	-s1s23 c5-c1 s5	oy	s1s23 s5 -c1s5	ay	s1c23	py	-s1s23c5l5-c1 s5l5+s1c23d4 + l2 s1c2
nz	c23 c5	oz	-c23 s5	az	s23	pz	c23c5l5+s23 d4 + s2 l2

3. Establishing homogeneous transformation along different coordinate axes

As shown in Fig.1 and Table.1, the last link tip coordinate system $O_4X_4Y_4Z_4$ can be expressed in the hip coordinate system $O_0X_0Y_0Z_0$, and transformation parameters can be given as follows:

Table 3 Transformation parameters of the coordinate system

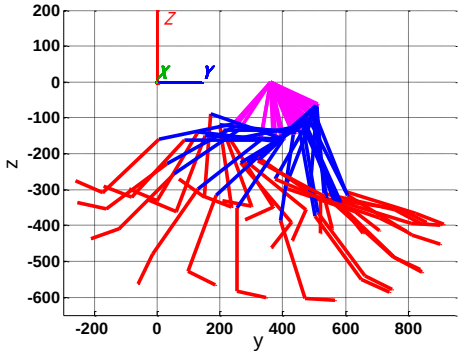
Link i	Joint angle θi/°	Joint offset i di/mm	Link Length li/mm	Twist angle αi/ °	Rotate about Y axis/ °	Translate along Y axis
1	θ1	0	0	90	0	0
2	θ2	0	l_2	0	0	0
3	θ3	0	0	0	90	0
4	θ5	d4	0	0	0	l4

As shown in Table.2, rotating coordinate transform about Y axis has been added to the transformation between the coordinate system $O_2X_2Y_2Z_2$ and coordinate system $O_3X_3Y_3Z_3$, so the homogeneous transformation matrix becomes more simpler and accurate. The same conclusion can still be obtained by applying the following transformation between the coordinate system $O_3X_3Y_3Z_3$ and coordinate system $O_4X_4Y_4Z_4$ as shown in Table 2. And in the end, the equation established based on Table.2 has the same computing result as that solved in Eq.(2), but this approach discussed in this paragraph is more simpler and more efficient.

Simultaneously, we apply this method to the constructing proceed of one bionic mechanism, and the kinematic equation can be shown in Eq. (3):

$$T_{forelimb} = T_{scapular}T_{shoulder}T_{elbow}T_{wrist}T_{toe} \quad (3)$$

In the end, we get the real result of the trajectory while the animal running at a high speed[2], and the final simulation result can be shown as follows:



UNIT: mm

Fig.2 A sequence of the running limb

4. Conclusion

In this paper, we have discussed a new method about the kinematic model construction for the serial robot, especially the robot with a complex spatial mechanism. And DH rule is a mature method for constructing the kinematic model for the serial mechanism, but not for all the heterogeneous spatial mechanism, so the method transforming the kinematics coordinate system along Y axis is presented. And this method is also validated through the paper of the postgraduates as discussed in [3] and [4] etc. And the computed results of the bionic mechanism shows that the method could solve the kinematic model simply for beginner.

Acknowledgement

This work is financially supported by the support from TUTE(KYQD13012).

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