

A Fast Conversion Method of Tube Coordinates

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Abstract. Inspired by the idea of the coordinate transformation of the robot arm, the tube structure is analogized to the robot arm structure, and the conversion method of the tube bend processing parameters LRA to the three-dimensional coordinate points is obtained. The method first regards the tube as a "mechanical arm"; then, using the similarity of the LRA processing parameters and D-H parameters, all the LRA parameters are converted into D-H parameters; finally, the D-H parameter method is applied to calculate the distance between each axis of the "mechanical arm". If the first space coordinate point is defined as the origin of the base coordinate system (0,0,0), then the position of the origin of other coordinate systems in the base coordinate system can be obtained; It has been proved by experiments that this method fast and feasible.

Keywords: Tube Coordinates; Fast Conversion Method; Mechanical Arm; D-H Parameter Method.

1. Introduction

Tubes are responsible for the transmission of fuel, coolant and other gases or liquids in equipment in the fields of automobiles, aerospace, ships, and nuclear power, and play an important role similar to human blood vessels [1]. With the increasing demand of miniaturization and precision of industrial products, the size and shape of the conduits are also becoming more and more complex[2], which increases the difficulty of converting the coordinates of the tubes. When the tube bender produces the tube, it needs to input the LRA parameters of the tube bend, but when designing the tube, we can only obtain the three-dimensional coordinates of the key points of the tube. In the flexible assembly process[3], we may not be able to determine the three-dimensional coordinates of the conduit, so we need to convert the coordinates of the tube; In reverse engineering[4], we only have the physical tube, but not its model. In order to obtain the model of the tube, this also requires the transformation of the tube coordinates.

To solve the above problems, inspired by the structure of the articulated arm robot, this paper proposes a fast conversion method from the LRA parameters of the tube to the XYZ three-dimensional coordinates based on the similarity between the tube structure and the articulated robot. First, the straight and curved segments of the tube are divided to make them equivalent to the links and joints of the robotic arm respectively; then, according to the geometric relationship, the LRA parameters are converted to D-H parameters; finally, according to the link transformation of the robotic arm In theory, that is, the D-H parameter method, the format conversion of the data is completed by using the D-H parameter data.

2. Relationship between Parameters

2.1. LRA and 3D Coordinates

A LRA parameter is composed of three values, which represent the size of the movement in the three directions when the tube bender transfers the tube blank[5]. The meanings of the three values are as follows[6]:

(1)L is the length value of the straight-line segment between the end point and the curved segment or between two curved segments, and it is the straight-line feed distance of the tube bender before processing each bend.

(2)R is the angle value of the space angle, which is the angle between the planes where the two bends are when the two bends are not on the same plane. It is the angle of rotation of the chuck of the tube bender to hold the tube.

(3)A is the value of the bending angle, which is the angle between the extension of the next straight-line segment and the previous straight-line segment. For a tube bender, it is the angle of rotation of the bending die.

The shape of the elbow can be represented by several key points and the bending radius corresponding to each key point in the three-dimensional coordinate system. The relationship between these key points and LRA is shown in the following figure:

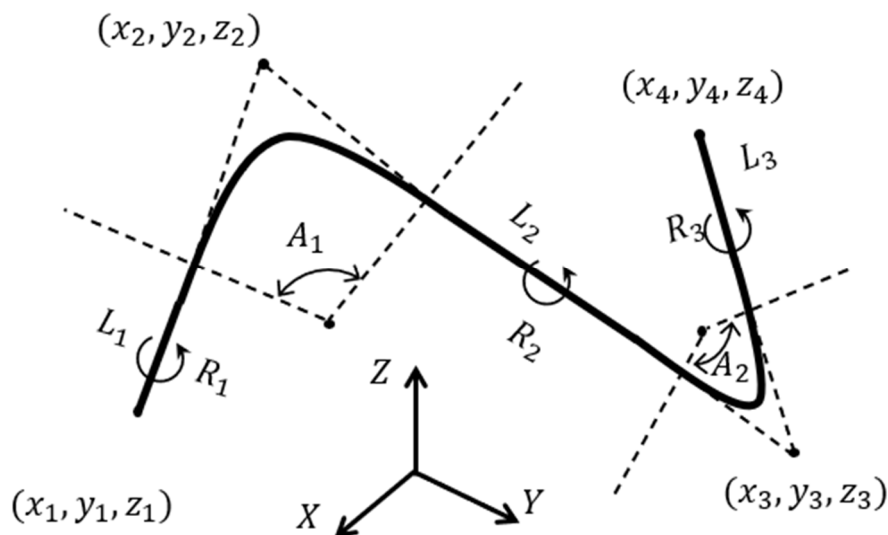


Figure 1. Schematic diagram of YBC data description of tube

The key points of the duct include the two end points of the duct and the intersection of the extension lines of adjacent straight line segments in the duct[7]. It can be seen from Figure 1 that the relationship between LRA and 3D coordinates are as follows:

(1) The number of LRA parameters is the number of three-dimensional coordinate points minus one.

(2) The LRA describes the relative positional relationship, while the three-dimensional coordinate system describes the absolute positional relationship [8]. Therefore, a tube can have an infinite array of 3D coordinates to describe it (different coordinate system positions), but only a single set of LRA parameters.

(3) All of them can fully describe the entire bend.

2.2. LRA and D-H Parameters

The D-H parameter method is to establish a series of coordinate systems on the joints connecting the links, and use homogeneous coordinate transformation to describe the relative position and

direction between these coordinates [9]. Using this method to establish the kinematic equation of the robot, the position and direction of each joint coordinate system can be well known. The D-H parameters are the four variables[10] required to apply this method. The four variables are: torsion angle α , link length a , joint angle θ and offset d .

However, when we consider the tube as a "mechanical arm", the LRA parameters are found to be very similar to the three parameters in D-H. The tube is divided into a straight segment and a curved segment, the straight segment is equivalent to the link of the mechanical arm, the curved segment is equivalent to the joint of the mechanical arm, and the tube structure is equivalent to the mechanical arm structure. , the rotation angle R value in the LRA parameter is equivalent to the joint angle θ value in the D-H parameter, and the bending angle A value is equivalent to the torsion angle α value in the D-H parameter. The value of the connecting rod length a in the D-H parameter can be calculated according to the L value in the LRA parameter. The relationship between L and a is shown in Figure 2:

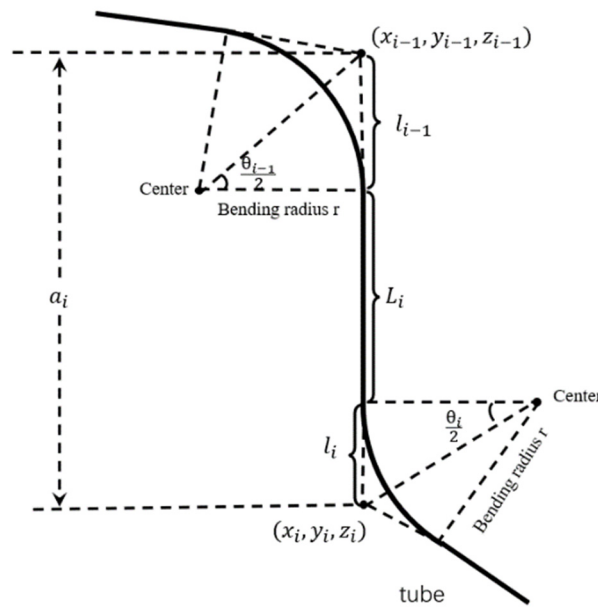


Figure 2. The relationship between L and a

It can be seen from Figure 2 that the relationship between the i -th connecting rod length a_i and the parameter L_i is:

$$\begin{cases} l_i = r \times \tan \frac{\alpha_i}{2} \\ a_i = l_{i-1} + L_i + l_i \end{cases} \quad (1)$$

where α_i is the i -th twist angle, and i is an integer greater than 0 and less than or equal to the number of turning angles.

Since the feeding direction of the tube bender is always the L -axis direction, the value of d_i is always 0. Therefore, the D-H parameters of the elbow can be completely obtained through the LRA parameters.

3. Coordinate Transformation

The process of coordinate transformation is shown in Figure 3:

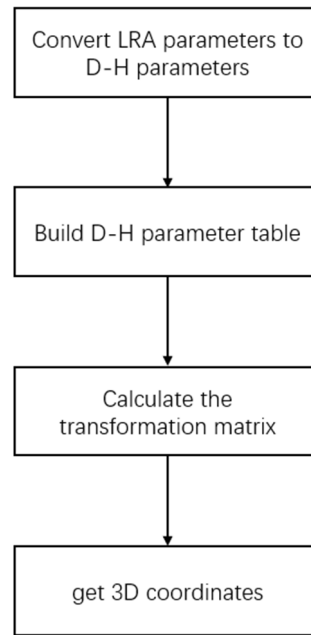


Figure 3. Coordinate conversion flow chart

According to the content described in Section 1, the tube and the mechanical arm have similarities in structure, so the D-H parameter method can be used for coordinate transformation. First, the LRA parameters are converted into D-H parameters in order to apply the D-H parameter method; then, the D-H parameter table is established; after that, the transformation matrix is calculated according to the D-H parameter method; finally, the three-dimensional coordinates are obtained according to the transformation matrix.

The form of the transformation matrix is shown in Equation 2:

$${}^{i-1}_iT = \begin{bmatrix} \cos\beta_{i-1} & -\sin\beta_{i-1} & 0 & a_{i-1} \\ \sin\beta_{i-1}\cos\theta_{i-1} & \cos\beta_{i-1}\cos\theta_{i-1} & -\sin\theta_{i-1} & -d_i\sin\theta_{i-1} \\ \sin\beta_{i-1}\sin\theta_{i-1} & \cos\beta_{i-1}\sin\theta_{i-1} & \cos\theta_{i-1} & d_i\cos\theta_{i-1} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

It is worth noting that the starting point of the three-dimensional coordinates of the tube obtained by this method is the origin of the reference coordinates.

4. Experiment

In order to verify the method described in this paper, the tube shown in Figure 4 was used for experiment. Table 1 shows the LRA and other parameters of the tube.

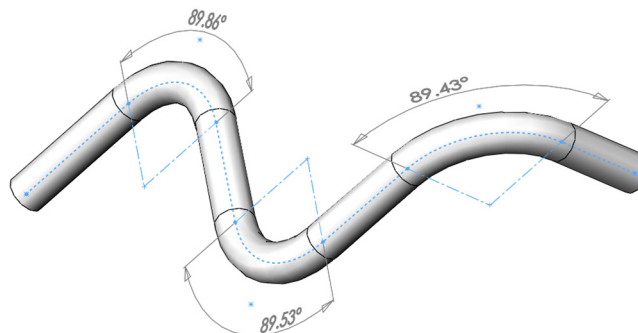


Figure 4. Catheter model diagram

Table 1. Elbow parameter table

No.	Length/mm	Rotation/(°)	Angle/(°)	Bend radius/mm	Diameter/mm
1	175.162	0.000	89.432	200.000	76.000
2	233.429	-88.192	89.526	200.000	76.000
3	241.116	179.738	89.855	200.000	76.000
4	284.127	0.000	0.000	0.000	76.000

First, the LRA parameters are converted into D-H parameters and the D-H parameter table is established.

Table 2. D-H parameter table

No.	$\alpha_{i-1}/(^{\circ})$	a_{i-1}/mm	d_i/mm	$\theta_i/(^{\circ})$
1	0	0	0	0
2	89.432	373.189	0	0
3	89.526	629.803	0	-88.192
4	89.855	638.963	0	179.738
5	0.000	483.622	0	0

Then, the D-H parameter method is applied to obtain the three-dimensional coordinate value of the tube. Table 3 shows the experimental results.

Table 3. Experimental results

No.	X/mm	Y/mm	Z/mm
1	0	0	0
2	373.189	0	0
3	379.433	629.777	0
4	359.327	635.263	-638.623
5	361.999	1118.868	-635.777

In order to verify the correctness of the result, we use the LRA to YBC function (xyz2ybc) provided in matlab to obtain the LRA parameter data of the tube and then compare it with the original parameters. The results are consistent with the original parameters. This shows that our method is effective and error-free.

5. Conclusion

In this paper, a method for fast transformation of tube coordinates is proposed. Firstly based on the structural similarity between the elbow and the mechanical arm, the straight section of the elbow is equivalent to a connecting rod, and the curved section of the elbow is equivalent to a joint. Afterwards, the LRA parameters are converted into D-H parameters based on the correlation between the LRA parameter data and the D-H parameter data. Finally, the transformation from YBC data format to XYZ data format is completed by applying the transformation theory of manipulator link. The experimental results show that the method is simple, feasible and has very high data conversion accuracy.

Acknowledgments

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