

Analysis on the workspace of palletizing robot based on AutoCAD

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Abstract. In this paper, a four-degree-of-freedom articulated palletizing robot is used as the object of research. Based on the analysis of the overall configuration of the robot, the kinematic mathematical model is established by D-H method to figure out the workspace of the robot. In order to meet the needs of design and analysis, using AutoCAD secondary development technology and AutoLisp language to develop AutoCAD-based 2D and 3D workspace simulation interface program of palletizing robot. At last, using AutoCAD plugin, the influence of structural parameters on the shape and position of the working space is analyzed when the structure parameters of the robot are changed separately. This study laid the foundation for the design, control and planning of palletizing robots.

1. Introduction

In recent years, considerable achievements have been made in the research of the workspace of palletizing robot[1]. G. Shanmugasundar[2] et al make the robot mechanical configuration design and modeling and simulation of the workspace of robot in CATIA 3D modelling software, which proved that the robot is totally capable of perform the given task. Zhang Ming[3] et al analyze the workspace of joint type stacking robot to get the reachable workspace diagram. Xu Chengyi[4] et al give a simple method of collision checking through simulation of joint driving by rotate3d function based on AutoCAD. Yin Feng[5] et al Advanced a new method based on the local point quadrant pattern which shown that it is accurate enough for extracting the workspace boundary of the robot. In this paper, using AutoLisp language the workspace of the four-degree-of-freedom joint stacking palletizing robot is drawn and simulation is constructed. The influence of structural parameters on the shape and position of workspace is analyzed intuitively. It also provides a powerful help for the design and research of palletizing robot.

2. Workspace of Palletizing Robot

According to the D-H parameter, the four-degree-of-freedom palletizing robot link coordinate system is established. See Figure 1. Then the position and attitude of the end of manipulator can be obtained:

$$T = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

According to the D-H parameter, the four-degree-of-freedom palletizing robot link coordinate system



Where: $\begin{bmatrix} n_x & o_x & a_x \\ n_y & o_y & a_y \\ n_z & o_z & a_z \end{bmatrix}$ is the rotation matrix (attitude) of the robot end coordinate system with respect

to base coordinate system; $\begin{bmatrix} p_x & p_y & p_z \end{bmatrix}^T$ is the center of the end effector of the robot. D-H parameters are shown in Table 1.

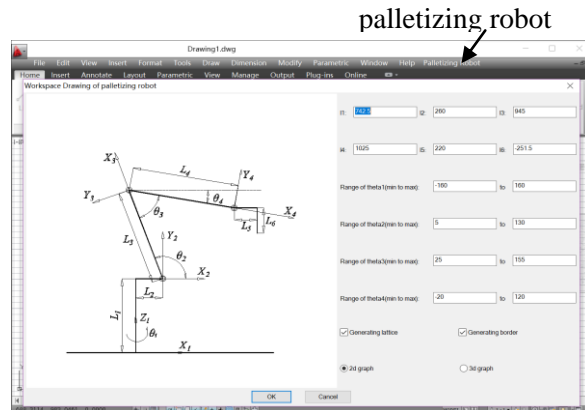
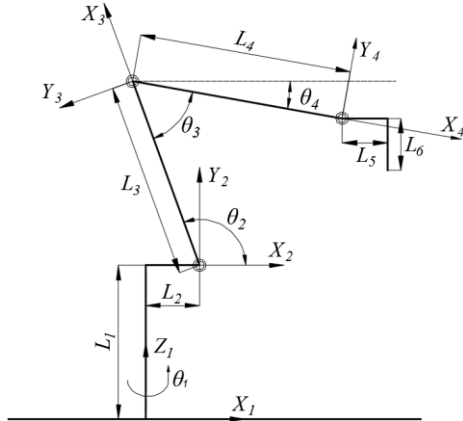


Figure 1. Mechanism coordinate system. **Figure 2.** Palletizing robot workspace software interface.

Table 1. Palletizing robot D-H parameter table.

i	a_{i-1} (mm)	α_{i-1} (°)	d_i (mm)	θ_i (°)
1	0	0	0	θ_1
2	l_2	-90°	l_1	0
3	l_3	0	0	θ_3
4	l_4	0	0	θ_4

3. The AutoCAD plug-in in the workspace of palletizing robot

In the AutoCAD development environment Visual Lisp, using AutoLisp language the file "palletizing robot.lsp" is written to realize the simulation of the workspace of palletizing robot. And generating the format dialog interface file "*.dcl". The dialog interface file achieves the loading and display of dialog box, After the user clicks on the "OK" button, the data is gotten from the edit box and check box. At the same time closing the dialog box to complete the following procedures for the drawing command of the workspace. Adding a custom menu "palletizing robot" in AutoCAD menu bar. The custom command macro loads the "palletizing robot.lsp" source file and the "*.dcl" dialog box. The final software interface is shown in Figure 2.

4. Drawing the workspace of palletizing robot

When the bottom rotary angle θ_1 keeps constant, the workspace of palletizing robot in the plane XOZ is analyzed. Figure 1 shows that in the XOZ plane the ranges of θ_2 、 θ_3 、 θ_4 have the relation as follow:

$$\theta_2 + \theta_3 + \theta_4 = 180^\circ \quad (2)$$

Where any two angles increase from the minimum value of the angle to the maximum value, which is constituting a dual loop. In this loop, the third angles are judged within the scope of the request. If consistent, the result of the coordinate point of the equation (1) is obtained, as shown in Figure 3.

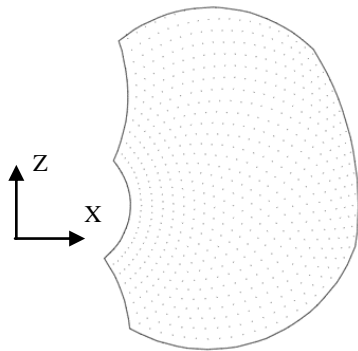


Figure 3. Lattice and boundary diagram of 2D workspace.

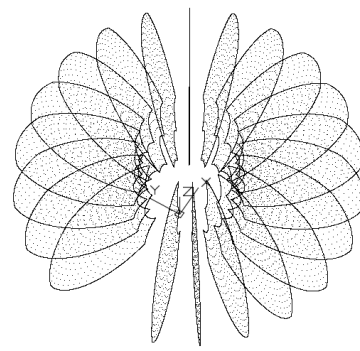


Figure 4. Lattice and boundary diagram of 3D workspace.

Analysis on the formation conditions of the workspace boundary can be seen: Firstly, it can be seen that each boundary is an arc, because one angle is fixed and the other angle is gradually increased when drawing each boundary. Secondly, when one of θ_2 、 θ_3 、 θ_4 is equal to the upper limit and lower limit of the angle range, one of workspace boundary is formed, so the maximum number of boundary of workspace should be 6; when any two angles equal to the upper limit and the lower limit of the respective angle range, one vertex of the workspace is formed. Thus, the method of three points to determine the arc can be used to draw the workspace boundary. The center point of the arc can be determined by taking the intermediate value of the angle range.

Therefore, running the AutoLisp program to draw the lattice and boundary diagram of 2D workspace, as shown in Figure 3. 3D workspace can be rotated by the 2D workspace along the Z axis, as shown in Figure 4.

5. The Influence of Structural Parameters on the Workspace of the Palletizing Robot

The influence of structural parameters on the workspace is analyzed by simulation and drawing. The original value of the parameter changes as shown in the spacing in Figure 5-7. The original workspace is represented by thick lines; the changing figure boundary is represented by thin lines.

5.1. The Influence of the Changing Rod

As can be seen from Figure 5, l_1 and l_2 only affect the position of the workspace, and the workspace moves toward the forward direction of the Z axis and the X axis.

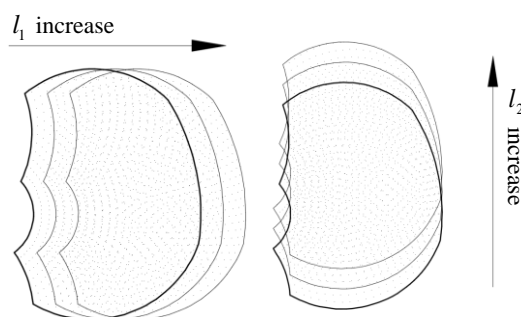


Figure 5. When the length of l_1 and l_2 change, the variation of the workspace.

As shown in Figure 6, when the other parameters are constant and l_3 increase or decrease, 2D workspace is deformed along the direction of the arrow. But the workspace is always composed of six arcs. l_4 is also shown in Figure 6.

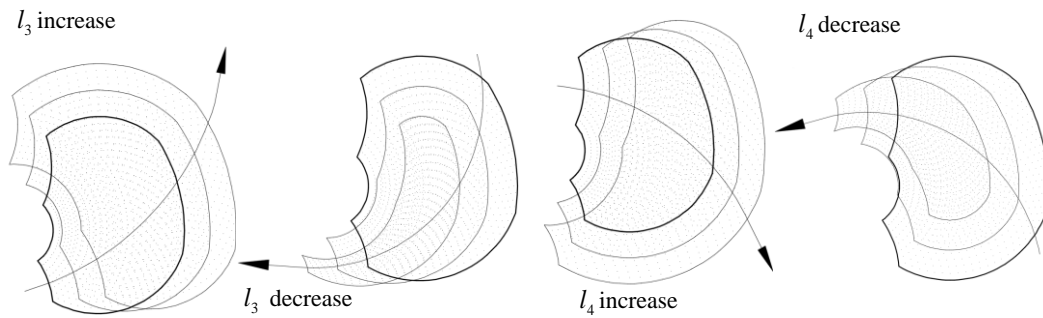


Figure 6. When the length of l_3 and l_4 changes, the variation of the workspace.

5.2. The Influence of the Changing Angle

Because the angle θ_1 is the bottom rotary angle, only the changes of θ_2 and θ_3 are analyzed. the 3D workspace changes the rotation range as the angle θ_1 range changes.

When the range of θ_2 is enlarged, the workspace is deformed along the direction of the arrow shown in Figure 7, and the workspace is gradually increased, otherwise, the reverse. In the both cases, it is possible that a boundary of the workspace is degraded into a point so that the resulting workspace boundary arc is less than 6. It is the same for θ_3 .

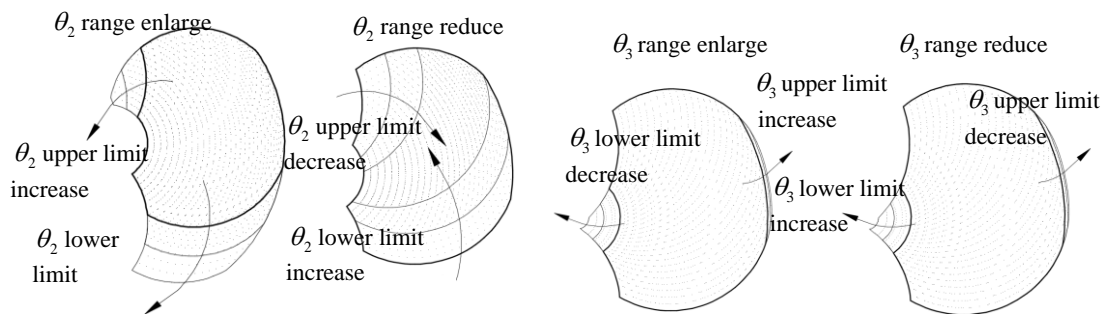


Figure 7. When the length of θ_2 and θ_3 changes, the variation of the workspace.

6. Conclusion

This paper studies the workspace of four-degree-of-freedom articulated palletizing robot by a secondary development on the AutoCAD platform. The robot is modeled according to D-H parameter method. This paper develops a simulation interface platform of workspace of palletizing robot in which the drawing of 2D and 3D workspace of robot is realized. The workspace is drawn by changing the input parameters. The influence of structural parameter change on workspace can be analyzed. This is a clear, simple and effective method for determining the workspace of palletizing robots, and it lays a foundation for the study of robot dynamics, control and planning.

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