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# Research on The Simulation of Robotic Motion Based Onmatlab

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**ABSTRACT:** According to certain requirements, the parameters of a welding robot are designed, and the kinematics problems of the robot are discussed.Then,The simulation of the forward kinematics,inverse kinematics of the robot is carried out in the MATLAB environment.The movement of each joint of the robot is observed by simulation.The required data is obtained, and the designed parameters are correct so that the desired target can be achieved..

**Keywords:** robot;kinematics; matlab;robotics toolbox; simulation

## I. INTRODUCTION

With the development of science and technology, robots are becoming more and more close to human beings. Out of interest and concern for robots, people want to know more about robots.Therefore,learning, teaching and training of robots is particularly important.To be important,however, the robot is a relatively expensive device so that when robots are taught, it is impossible to teach them with many practical robots.Then it is necessary to use robot simulation which can provide a convenient and flexible testing tool. The robot can be simulated by graphic simulation.The fruit is represented in graphical form, thus visually showing the status of movement generating the data curve or many important informaton which is is difficult to analyze by the data itself .Law of motion under certain control conditions can be seen from the graphics.

The robot kinematics,in the domestic related works,are talked more on the PUMA and Standford robots, and this article discusses one kind of welding robot while using MATLAB language for simulation. Currently,MATLAB has become one of the most popular software in the control community,In addition to the traditional interactive programming, it also provides rich and reliable Matrix operations, graphics rendering, data processing, image processing, Windows programming and other convenient tools.The MATLAB is becoming more and more popular in China.It will be ideal for robot simulation on PC machines.Based on what mentioned above, this paper first establishes the model of the welding robot.Then the forward and inverse kinematics algorithms and trajectory planning are discussed in detail. Finally,Using Robotics Toolbox and simple program,the kinematics simulationin is rapidly completed in the MATLAB environment.In the process, not only the movement of the robot is observed intuitively, but also the required data which is displayed in graphical form.

## II. PARAMETER DESIGN OF WELDING ROBOT

### 2.1 D-H transformation

Denavit and Hartenberg proposed a general position description method in 1955, using homogeneous transformation matrix to describe the relationship between the relative pose of connecting rod.the utility model has the advantages of the relative relationship between the robot and the base coordinate system through matrix operations,easy to calculate. The D-H parameter method is a general method of position and orientation description, which describes the motion relations of mechanisms using link parameters. First of all, each joint and connecting rod should be numbered. The rules are as follows: the base is generally regarded as the connecting rod 0, the first movable connecting rod is the connecting rod 1, and so on, and the robot end connecting rod is a connecting rod n. According to the D-H parameter method, the definition of the bar coordinate system is presented three connecting rod adjacent to each other for robot, as shown in Fig-1.

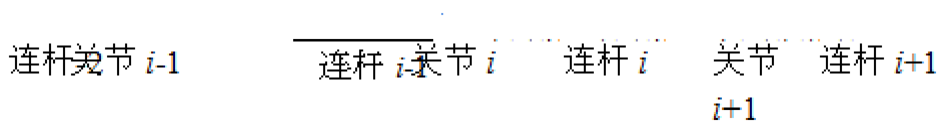



**Fig-1**:Geometric parameters and coordinate systems of links

**The rules for determining the coordinate system and parameters of a connecting rod are as follows:**
1) the direction of the coordinate axis $Z_i$is consistent with the axis of motion of the *i+1* joint.
2) the coordinate axis *Xi* is consistent with the common vertical of $Z_i$and $Z_{i-1}$, and is directed at the coordinate axis $Z_{i+1.}$
3) coordinate axis $Y_i$ is established according to the right hand Cartesian coordinate system.
4) the public vertical line $a_i$ is the shortest distance between two axes of axis $Z_i$ and $Z_{i-1}$, calling $a_i$ the length of the connecting rod.
5) the distance between the normal vertical line $a_{i-1}$ and $a_i$is called offset $d_{i.}$
6) the angle between the axis $X_{i-1}$ and $X_i$ is $\theta_{i..}$and the axis is $Z_{i-1}$, the right turn is positive, and the $\theta_i$ is the rotation angle.
7) the angle between the axis $Z_{i-1}$ and $Z_i$ is $\alpha_{i.}$ the rotation of the axis around the $X_i$ axis is positive, and the $\alpha_{i.}$ is called the torsion angle.

From Fig-1, the relative pose between the rods *i-1* and *i* are completely determined by four parameters $a_i$,$d_i$,$\alpha_i$ and $\theta_{i\,.}$*T*hese four parameters are called D-H parameters, and is often referred to as kinematic parameters or geometry parameters.the first three parameters are called structure parameters of the robot. Each link of robot contains four parameters $a_i$,$d_i$,$\alpha_i$ and $\theta_{i\,.}$ They determine the robot kinematics morphology of each link, these parameters can be constructed as *i-1* coordinate system and coordinate system *i*, namely the homogeneous transformation matrix between the joint. The specific steps are as follows:
1) rotation of the axis $Z_{i-1}\theta_i$ angle, then the axis $X_{i-1}$ and $X_i$ are in the same plane.
2) the translational distance of $Z_{i-1}$ along the axis is $d_i$, then the axis $X_{i-1}$ is collinear with $X_{i.}$
3) translation distance $a_i$ along the axis $X_i$, then the origin of the coordinate system of the connecting rod *i*-1 coincides with the origin of the connecting rod *i*;
4) rotation of the axis $X_i\alpha_i$ angle, then the $Z_{i-1}$is collinear with the $Z_i$.

The above four steps can be expressed in the form of homogeneous transformation matrix.and the homogeneous transformation matrix between the coordinate system I-1 and the coordinate system I can be obtained by multiplying the four homogeneous transformation matrices in turn:

$$
{}^{i-1}T_i = Rot(z_i,\theta_i)Trans(0,0,d_i)Trans(a_i,0,0)Rot(x,\alpha_i)
$$

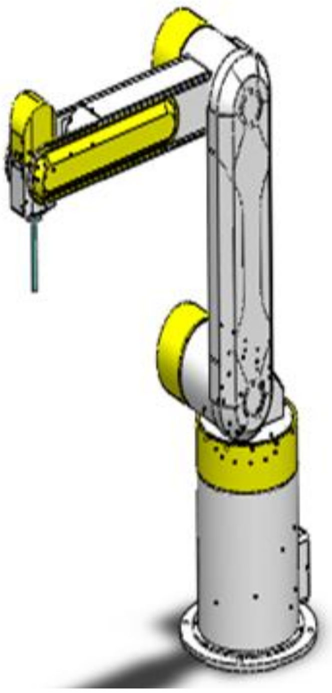
$$
= \begin{bmatrix} \cos\theta_i & -\sin\theta_i & 0 & 0 \\ \sin\theta_i & \cos\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha_i & -\sin\alpha_i & 0 \\ 0 & \sin\alpha_i & \cos\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

$$
= \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & a_i\cos\alpha_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

For robots with n links, according to the above rules, the matrix of each joint can be established, thus the coordinate transformation from the robot base coordinate system to the end can be realized:

$$
{}^0T_n = {}^0T_1\,{}^1T_2 \cdots {}^{i-1}T_i \cdots {}^{n-1}T_n
$$

**2.2 Establishment of welding robot connecting rod coordinate system based on D-H parameter method**
According to the D-H parameter method, a coordinate system is set up for each joint of the welding robot(Fig-2). As shown in Figure 3-3, the kinematic relation of the mechanism is described by connecting rod parameters.



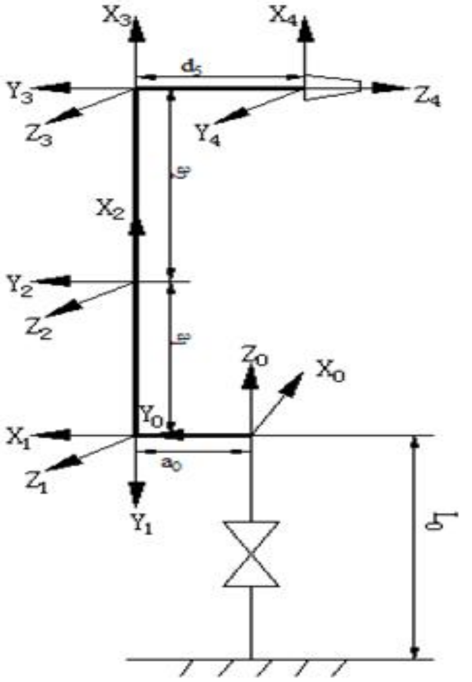



**Fig-2**: welding robot **Fig.3:** Connecting rod coordinate system

The nominal parameters of the robot connecting rod can be obtained from the technical documentation of the welding robot, as shown in table-1.

**Table-1:**Nominal parameters of links of UR3 robot

| 序号 | $a_{i-1}$(mm) | $\alpha_{i-1}$(°) | $d_i$(mm) | $\theta_i$(°) |
|---|---|---|---|---|
| 1 | 85 | -90 | 0 | 90 |
| 2 | 560 | 0 | 0 | -90 |
| 3 | 630 | 0 | 0 | 0 |
| 4 | 0 | 90 | 0 | 0 |
| 5 | 0 | 0 | 240 | 0 |

## III. ROBOT KINEMATICS SIMULATION ALGORITHM

### 3.1 Forward kinematics problem of robot

The robot is in direct motion to determine the position of the robot at the end of the robot relative to the robot's coordinate system. When the structure parameters and the joint rotation angle value between the robot links was determined, constructing the homogeneous transformation matrix,position and altitude can be obtained at the end of the robot relative to the base coordinate position by matrix operation,solving the kinematics of the robot. In the last section, the kinematics parameters of the welding robot are obtained, and five homogeneous transformation matrices can be obtained according to formula:

$$ {}_1^0T = \begin{bmatrix} \cos\theta_1 & 0 & -\sin\theta_1 & a_1\cos\theta_1 \\ \sin\theta_1 & 0 & \cos\theta_1 & a_1\sin\theta_1 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, {}_2^1T = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 & a_2\cos\theta_2 \\ \sin\theta_2 & \cos\theta_2 & 0 & a_2\sin\theta_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}_3^2T = \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & a_3\cos\theta_3 \\ \sin\theta_3 & \cos\theta_3 & 0 & a_3\sin\theta_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, {}_4^3T = \begin{bmatrix} \cos\theta_4 & 0 & \sin\theta_4 & 0 \\ \sin\theta_4 & 0 & -\cos\theta_4 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{4}_{5}T = \begin{bmatrix} \cos\theta_5 & -\sin\theta_5 & 0 & 0 \\ \sin\theta_5 & \cos\theta_5 & 0 & 0 \\ 0 & 0 & 1 & d_5 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

The kinematics transformation matrix of welding robot is:

$$ {}^{0}_{5}T = {}^{0}_{1}T\,{}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T\,{}^{4}_{5}T = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (3\text{-}1) $$

$$ n_x = c_1c_{234}c_5 - s_1s_5,\ n_y = s_1c_{234}c_5 + c_1s_5,\ n_z = -s_{234}c_5 $$

$$ o_x = -c_1c_{234}s_5 - s_1c_5,\ o_y = -s_1c_{234}s_5 + c_1c_5,\ o_z = s_{234}s_5 $$

$$ a_x = c_1s_{234},\ a_y = s_1s_{234},\ a_z = c_{234}\ \ p_x = d_5c_1s_{234} + a_3c_1c_{23} + c_1(a_2c_2 + a_1), $$

$$ p_y = d_5s_1s_{234} + a_3s_1c_{23} + s_1(a_2c_2 + a_1),\ p_z = d_5c_{234} - a_3s_{23} - a_2s_2 $$

Where: $c_{234}=cos(\theta_2+\theta_3+\theta_4)$

**3.2 Inverse kinematics problem of robot**

The inverse kinematics of robot is known as the position and orientation of the end link, and the joint variables of the robot are obtained. cThe solution of the inverse kinematics problem of robot is that the two ends of the motion equation are multiplied by the inverse matrix of ${}^{0}_{1}T$ , and the relative elements of both ends of the equation are equal, and the joint variables can be obtained.

$$ {}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T\,{}^{4}_{5}T = {}^{0}_{1}T^{-1} \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} c_{234}c_5 & -s_5c_{234} & s_{234} & d_5s_{234} + a_3c_{23} + a_2c_2 \\ s_{234}c_5 & -s_{234}s_5 & -c_{234} & -d_5c_{234} + a_3s_{23} + a_2s_2 \\ s_5 & c_5 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (3\text{-}2) $$

$$ = \begin{bmatrix} c_1n_x + s_1n_y & c_1o_x + s_1o_y & c_1a_x + s_1a_y & c_1p_x + s_1p_y - a_1 \\ -n_z & -o_z & -a_z & -p_z \\ -s_1n_x + c_1n_y & -s_1o_x + c_1o_y & -s_1a_x + c_1a_y & -s_1p_x + c_1p_y \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ \begin{cases} \theta_1 = \arctan(\dfrac{p_y}{p_x}) \\ \theta_2 = \arccos(\dfrac{F_1F_3 \pm F_2\sqrt{F_1^{\,2} + F_2^{\,2} - F_3^{\,2}}}{F_1^{\,2} + F_2^{\,2}}) \\ \theta_3 = \arccos(\dfrac{F_1^{\,2} + F_2^{\,2} - a_2^{\,2} - a_3^{\,2}}{2a_2a_3}) \\ \theta_4 = 180^\circ - \arccos(\dfrac{F_1F_3 \pm F_2\sqrt{F_1^{\,2} + F_2^{\,2} - F_3^{\,2}}}{F_1^{\,2} + F_2^{\,2}}) - \arccos\left(\dfrac{F_1^{\,2} + F_2^{\,2} - a_2^{\,2} - a_3^{\,2}}{2a_2a_3}\right) \\ \theta_5 = 0^\circ \end{cases} $$

## IV. DYNAMIC SIMULATION BASED ON MATLAB

### 4.1 Simulation of Forward kinematics

When the welding robot is in some special position, its joint angle is used to verify the positive solution. For Example,when $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0^\circ$, it was substituted into the position equation(3-1):

$$ {}_5^0T = \begin{pmatrix} 1 & 0 & 0 & a_3 + a_2 + a_1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_5 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

To facilitate simulation, assume $a_1 = a_2 = a_3 = d_5 = 1$(the same below). Through the MATLAB simulation, when $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0^\circ$, as shown in Figure-4, the coordinate value of the end effector in the base coordinate system is $(a_3 + a_2 + a_1 \quad 0 \quad d_5)$.

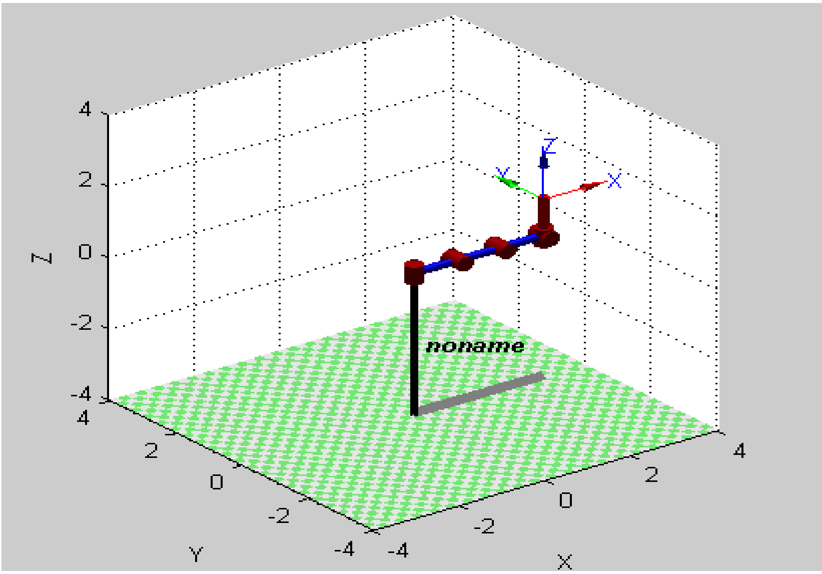



**Fig-4:** The attitude of robot

### 4.2 Simulation of Inverse kinematics

It is assumed that $a_1 = a_2 = a_3 = d_5 = 1$ ,given joint variable is $\theta_i = (0^\circ \quad -90^\circ \quad 90^\circ \quad 180^\circ \quad 0^\circ)$, $i = 1 \cdots 5$ ,then substituted into the equation (3-1) :

$$ {}_5^0T = \begin{pmatrix} -1 & 0 & 0 & a_3 + a_1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & -1 & a_2 - d_5 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

When $a_1 = a_2 = a_3 = d_5 = 1$, as shown in Figure-5, the coordinate values of the end effector in the base coordinate system are $\theta_i = (0^\circ \quad -90^\circ \quad 90^\circ \quad 180^\circ \quad 0^\circ), i = 1 \cdots 5$. The simulation results of Matlab are consistent with the formula. The inverse kinematics formula is correct.

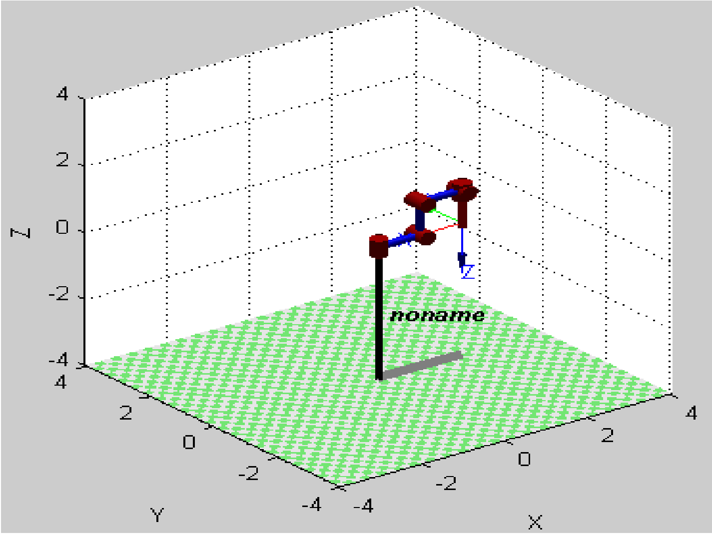



**Fig-5:** The attitude of robot

## V. CONCLUSION

This paper designs the parameters of welding robot and analyses itskinematics problems.In the MATLAB environment, the preparation of simple program statements to simulate the robot kinematics,verified the rationality of the parameters, achieving good results.

## REFERENCES

[1]. Shanahan M.A cognitive architecture that combines internal simulation with a global[J].Cognition and Consciousness,2006,15(2),20-25.
[2]. Wang Lu-min.Movenment simulation of teaching robot based on MATLAB[J].Machinery & Electronics,2005(9):55-57.
[3]. Driels M R, Swayze L W, Potter L S. Full-pose calibration of a robot manipulator using a coordinate-measuring machine[J]. The International Journal of Advanced Manufacturing Technology, 1993, 8(1): 34-41.
[4]. Corke P I.A robotics toolbox for matlab[J]. Robotics and Automation Magazine,1996,3(1):24-32.
[5]. Zhuang H, Roth Z S. A linear solution to the kinematic parameter identification of robot manipulators[J]. IEEE Transactions on Robotics and Automation, 1993, 9(2): 174-185.
[6]. Zhuang H, Roth Z S, Hamano F. A complete and parametrically continuous kinematic model for robot manipulators[J]. IEEE Transactions on Robotics and Automation, 1992, 8(4): 451-463

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