Group7 Lab1
Introduction to Dobots

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Abstract

The experiment laboratory is divided into two parts. First, we formed a team, connected the Dobot to our computer, and controlled it to perform simple motions, recording a video as proof of successful operation. In the second part, we analyzed the robot's forward kinematics by constructing its kinematic tree and calculating homogeneous transformation matrices with the help of MATLAB. Our final result confirmed that the theoretical calculations matched the computational results.

1 Introduction

This lab focuses on understanding the kinematics and control of the Dobot Magician Lite robotic arm. It is divided into two parts. In the first part, we formed group 7 (Andy, Ganesh, and Michael), connected our computer to the Dobot, and controlled it to perform simple motions. We also recorded a video to demonstrate this.

In the second part, we analyzed the forward kinematics of the Dobot by drawing its kinematic tree and calculating the homogeneous transformation matrices for verifying our results and the given data.

2 Method

For the first part of this lab, we formed a group of three, consisting of Andy, Ganesh, and Michael. We then connected our computer to the Dobot and controlled it to perform simple motions.

For the second part, we first drew our kinematic tree, as shown in Figure 1. Next, we used the rotation and projection matrices to compute the homogeneous transformation matrices for each joint $({}^1T_2 \sim {}^3 T_4)$ and the final transformation matrix from the base to the end-effector $({}^1T_4)$. With the help of MATLAB, we computed all the transformation matrices and obtained the final result. During the calculations, we used the effective joint angles instead of the input angles, as defined in Equation 1.

$$
\begin{aligned}
\theta_1^{\text{eff}} &= \theta_1^{\text{input}} \\
\theta_2^{\text{eff}} &= \theta_2^{\text{input}} \\
\theta_3^{\text{eff}} &= -\theta_2^{\text{input}} + \theta_3^{\text{input}} \\
\theta_4^{\text{eff}} &= \theta_4^{\text{input}}
\end{aligned}
\tag{1}
$$

3 Result

- **The kinematic tree**:

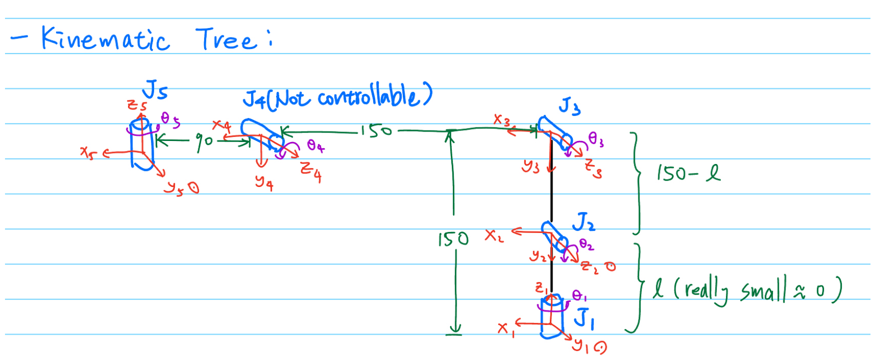

Figure 1: Our kinematic tree.

- **Handwritten process of computing homogeneous transformation.**

- Rotation Matrix ($R_{n(n+1)} = R_n \times PM_{n(n+1)}$)

$$R_1 = \begin{bmatrix} c\theta_1 & -s\theta_1 & 0 \\ s\theta_1 & c\theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad PM_{12} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix} \Rightarrow R_{12} = \begin{bmatrix} 1 & 0 & 0.0092 \\ -0.0092 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} c\theta_2 & -s\theta_2 & 0 \\ s\theta_2 & c\theta_2 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad PM_{23} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \Rightarrow R_{23} = \begin{bmatrix} 0.8158 & -0.5784 & 0 \\ 0.5784 & 0.8158 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} c\theta_3 & -s\theta_3 & 0 \\ s\theta_3 & c\theta_3 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad PM_{34} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \Rightarrow R_{34} = \begin{bmatrix} 0.8899 & -0.4561 & 0 \\ 0.4561 & 0.8899 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} c\theta_4 & -s\theta_4 & 0 \\ s\theta_4 & c\theta_4 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad PM_{45} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \Rightarrow R_{45} = \begin{bmatrix} 0.4622 & 0 & -0.8868 \\ -0.8868 & 0 & -0.4622 \\ 0 & 1 & 0 \end{bmatrix}$$

- Homogeneous Matrix:

$${}^1T_2 = \begin{bmatrix} \begin{bmatrix} R_{12} \end{bmatrix} & \begin{matrix} 0 \\ 0 \\ 0 \end{matrix} \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0.0092 & 0 \\ -0.0092 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^2T_3 = \begin{bmatrix} \begin{bmatrix} R_{23} \end{bmatrix} & \begin{matrix} 150 \cdot s\theta_2 \\ -150 \cdot c\theta_2 \\ 0 \end{matrix} \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.8158 & -0.5784 & 0 & 86.7594 \\ 0.5784 & 0.8158 & 0 & -122.3634 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^3T_4 = \begin{bmatrix} \begin{bmatrix} R_{34} \end{bmatrix} & \begin{matrix} 150 \cdot c\theta_3 \\ 150 \cdot s\theta_3 \\ 0 \end{matrix} \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.8899 & -0.4561 & 0 & 133.4898 \\ 0.4561 & 0.8899 & 0 & 68.4140 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^4T_5 = \begin{bmatrix} \begin{bmatrix} R_{45} \end{bmatrix} & \begin{matrix} 90 \cdot c\theta_4 \\ 90 \cdot s\theta_4 \\ 0 \end{matrix} \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.4622 & 0 & -0.8868 & 41.5949 \\ -0.8868 & 0 & -0.4622 & -79.8115 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^1T_4 = {}^1T_2 \times {}^2T_3 \times {}^3T_4 \times {}^4T_5 = \begin{bmatrix} 1 & 0.0092 & 0 & 246.0737 \\ 0 & 1 & 0 & -2.2617 \\ -0.0092 & 0 & 1 & -10.6557 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Computed X, Y, Z:

X: 246.0737 mm

Y: -2.2617 mm

Z: -10.6557 mm

Computed orientation:

$R = \theta_1 + \theta_4 = 89.4432$

Figure 2: The computing process of the final homogeneous matrix.

- **Final position verification**:
  As can be seen in Figure 3 and Figure 4, we successfully verify the given final position and orientation with MATLAB and our hand written idea. Also, the homogeneous matrix from the base to the end-effector is shown in Figure 4.

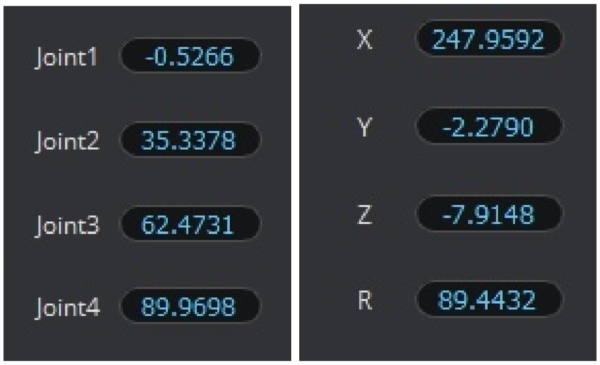

Figure 3: The image on the left is the angle of each joints. The one on the right is the final position and orientation of the end-effector.

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Homogeneous Transformation (base to E.E.):
    1.0000    0.0092    0.0000  246.0737
   -0.0092    1.0000    0.0000   -2.2617
    0.0000         0    1.0000  -10.6557
         0         0         0    1.0000

Computed End-Effector Orientation (degree):
Orientation: 89.4432

Computed End-Effector Position (mm):
X: 246.0737, Y: -2.2617, Z: -10.6557
```

Figure 4: The output from our code.

4 Conclusion

In this lab, we learned how to control the Dobot Magician Lite and analyze its forward kinematics. We built its kinematic tree, calculated transformation matrices, and used MATLAB to verify our results and the given data. By using effective joint angles, we ensured more accurate calculations. Overall, the lab helped us understand robotic motion and how theoretical kinematics apply in practice.

References

[1] Course Materials