Intro to Robotics

Zhuorui YUN

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1 Homework 3

For the first question, my answer and graph as belows:

[1]:
```
from sympy import symbols, cos, sin, sqrt, Matrix, simplify, atan
from sympy import init_printing
import matplotlib.pyplot as plt
from matplotlib.animation import FuncAnimation, PillowWriter
```

[2]:
```
# Variable initialization
theta1, theta2, theta3, d = symbols('theta1 theta2 theta3 d')
L0, L1, L2, L3, L4, L5 = symbols('L0 L1 L2 L3 L4 L5')

# -DH Matrix-
def DH_matrix(alpha, a, d, theta):
    return Matrix([
        [cos(theta), -sin(theta), 0, a],
        [sin(theta)*cos(alpha), cos(theta)*cos(alpha), -sin(alpha),␣
 ↪-sin(alpha)*d],
        [sin(theta)*sin(alpha), cos(theta)*sin(alpha), cos(alpha),␣
 ↪cos(alpha)*d],
        [0, 0, 0, 1]
    ])
```

[3]:
```
# Forward Kinematics
T01 = DH_matrix(0, 0, L0, theta1)
T12 = DH_matrix(0, sqrt(L1**2 + L2**2), d, -atan(L1/L2))
T23 = DH_matrix(0, L3, 0, theta2)
T34 = DH_matrix(0, L4, 0, theta3)
T45 = DH_matrix(0, L5, 0, 0)
T02 = T01 @ T12
T03 = T02 @ T23
T04 = T03 @ T34
T05 = T04 @ T45
T04 = simplify(T01 * T12 * T23 * T34 )
print("T04 = ")
T04
```

T04 =

[3]:

$$\left[\begin{array}{cccc} \frac{L_2\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(L_1\sin(\theta_1+\theta_2+\theta_3)+L_2\cos(\theta_1+\theta_2+\theta_3))}{L_1^2+L_2^2} & \frac{L_2\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(L_1\cos(\theta_1+\theta_2+\theta_3)-L_2\sin(\theta_1+\theta_2+\theta_3))}{L_1^2+L_2^2} & 0 & \frac{L_2L_3\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(L_1\sin(\theta_1)+L}{} \\ \frac{L_2\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(-L_1\cos(\theta_1+\theta_2+\theta_3)+L_2\sin(\theta_1+\theta_2+\theta_3))}{L_1^2+L_2^2} & \frac{L_2\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(L_1\sin(\theta_1+\theta_2+\theta_3)+L_2\cos(\theta_1+\theta_2+\theta_3))}{L_1^2+L_2^2} & 0 & \frac{-L_2L_3\sqrt{\frac{L_1^2+L_2^2}{L_2^2}}(L_1\cos(\theta_1)-L}{} \\ 0 & 0 & 1 & \\ 0 & 0 & 0 & \end{array}\right.$$

③ $L_0 = 1.2m, L_1 = 0.5m, L_2 = 0.5m, L_3 = L_4 = L_5 = 1m$, All the variables $d, \theta_2, \theta_2, \theta_3$ are moving wit constant speed in time [0,3] s. d starts with 0 m and ends with 1.2 m. θ_1 start with 0° and ends with 90°, θ_2 starts with 0° and ends with 150°, θ_3 starts with 90° and ends with -90°. My annotation is seen below: You can also approach the gif by this Link