HOME WORK #2

Pham Thi Ngoc Thao
20215435

(1)

$$^0_2T = \begin{bmatrix} c_1c_2 & -c_1s_2 & s_1 & l_1c_1 \\ s_1c_2 & -s_1s_2 & -c_1 & l_1s_1 \\ s_2 & c_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

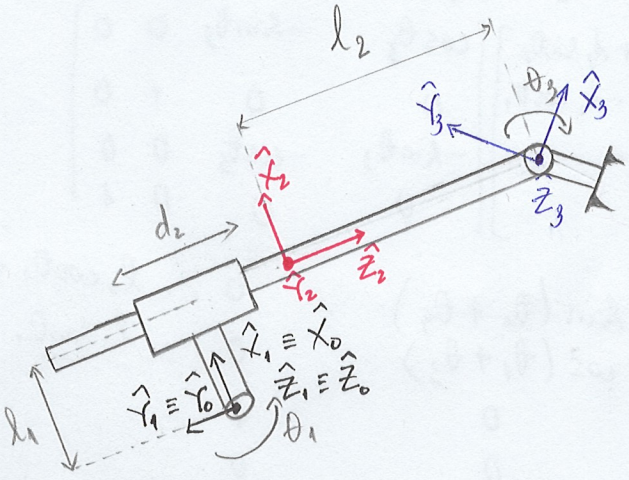
$$^0P_{Tip} = {}^0_2T\ {}^2P_{Tip} \quad ; \quad {}^2P_{Tip} = \begin{bmatrix} l_2 \\ 0 \\ 0 \end{bmatrix}$$

$$^0P_{Tip} = \begin{bmatrix} c_1c_2 & -c_1s_2 & s_1 & l_1c_1 \\ s_1c_2 & -s_1s_2 & -c_1 & l_2s_1 \\ s_2 & c_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} l_2 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} l_1c_1 + l_2c_1c_2 \\ l_1s_1 + l_2s_1c_2 \\ l_2s_2 \\ 1 \end{bmatrix}$$

Thus, $$^0P_{Tip} = \begin{bmatrix} l_1c_1 + l_2c_1c_2 \\ l_1s_1 + l_2s_1s_2 \\ l_2s_2 \end{bmatrix}$$

(2)

a) Assign link frames {0} through {3} for manipulator as the following picture



b)

i	a_{i-1}	α_{i-1}	d_i	θ_i
1	0	0	0	θ_1
2	l_1	90°	d_2	0
3	0	-90°	0	θ_3

c) We have:

$$ {}^0_3T = {}^0_1T\,{}^1_2T\,{}^2_3T $$

Besides,

$$ {}^0_1T = \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad {}^1_2T = \begin{bmatrix} 1 & 0 & 0 & l_1 \\ 0 & 0 & -1 & -d_2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^2_3T = \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\theta_3 & -\cos\theta_3 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

And the result would be:

$$ {}^0_3T = \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 & l_1 \\ 0 & 0 & -1 & -d_2 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\theta_3 & -\cos\theta_3 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ = \begin{bmatrix} \cos\theta_1 & 0 & \sin\theta_1 & l_1\cos\theta_1 + d_2\sin\theta_1 \\ \sin\theta_1 & 0 & -\cos\theta_1 & l_1\sin\theta_1 - d_2\cos\theta_1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -\sin\theta_3 & -\cos\theta_3 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ = \begin{bmatrix} \cos(\theta_1+\theta_3) & -\sin(\theta_1+\theta_3) & 0 & l_1\cos\theta_1 + d_2\sin\theta_1 \\ \sin(\theta_1+\theta_3) & \cos(\theta_1+\theta_3) & 0 & l_1\sin\theta_1 - d_2\cos\theta_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

3. Program Forward Kinematics for Puma 560 Robots using Matlab.

Matlab code:

```
clear all;
clc;

%DH parameter
alpha =  [0 -90 0 -90 90 -90] ; %link twist
a = [0 0 1 0.3 0 0]; %link length
d = [0 0  0.5 1 0 0]; %link offset
theta = [45 60 45 60 45 30]; % joint variable

P6_T = [0; 0; 0.2; 1];

%Apply forward kinematics joints
T = [];
for n = 1:6
       matT = [cosd(theta(n)) -sind(theta(n)) 0 a(n);
           sind(theta(n))*cosd(alpha(n))  cosd(theta(n))*cosd(alpha(n)) -
sind(alpha(n)) -sind(alpha(n))*d(n);
           sind(theta(n))*sind(alpha(n))  cosd(theta(n))*sind(alpha(n))
cosd(alpha(n)) cosd(alpha(n))*d(n);
           0 0 0 1];
        T = [T; {matT}];
end


T0_6 = T{1}*T{2}*T{3}*T{4}*T{5}*T{6}
P0_T = T0_6*P6_T
```

The result of T0_6

```
T0_6 =

    0.1567    0.5008   -0.8513   -0.7379
   -0.9468    0.3214    0.0148   -0.0308
    0.2810    0.8037    0.5245   -0.8970
         0         0         0    1.0000
```

And the result of P0_T

```
P0_T =

   -0.9082
   -0.0279
   -0.7921
    1.0000
```