R E P O R T

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

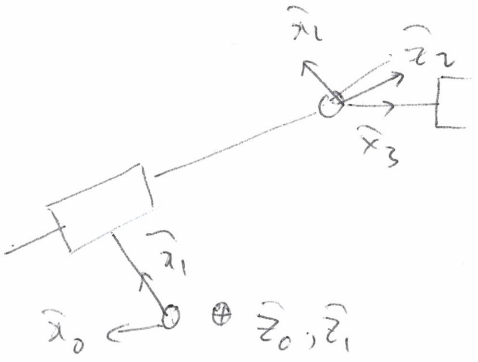
we have: ${}^2P_{tip}$ is $\begin{bmatrix} l_2 \\ 0 \\ 0 \end{bmatrix}$, ; ${}^0P_2 = \begin{bmatrix} l_1c_1 \\ l_1s_1 \\ 0 \end{bmatrix}$

Thus ${}^0P_{tip} = {}^0P_2 + {}^0R_2 \cdot {}^2P_{tip}$

$$= \begin{bmatrix} l_1c_1 \\ l_1s_1 \\ 0 \end{bmatrix} + \begin{bmatrix} c_1c_2 & -c_1s_2 & s_1 \\ s_1c_2 & -s_1s_2 & -c_1 \\ s_2 & c_2 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} l_1c_1 \\ l_1s_1 \\ 0 \\ 1 \end{bmatrix} \begin{bmatrix} l_2 \\ 0 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} l_1c_1 + l_2 \cdot c_1c_2 \\ l_2 \cdot s_1 + l_2 \cdot s_1 \cdot c_2 \\ l_2 \cdot s_2 \end{bmatrix}$$

(2)



The D-H table for this manipulator is:

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

The Forward kinematics for this manipulator ${}^0_3T$ is given by

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

$$= \begin{bmatrix} c\theta_1 & -s\theta_1 & 0 & 0 \\ s\theta_1 & c\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & l_1 \\ 0 & 0 & 1 & d_2 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} c\theta_3 & -s\theta_3 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ s\theta_3 & c\theta_3 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} c\theta_1c\theta_3 - s\theta_1s\theta_3 & -(c\theta_1 \cdot s\theta_3 + s\theta_1 \cdot c\theta_3) & 0 & l_1c\theta_1 - d_2 \cdot s\theta_1 \\ s\theta_1 \cdot c\theta_3 + c\theta_1 \cdot s\theta_3 & c\theta_1 \cdot c\theta_3 - s\theta_1 \cdot s\theta_3 & 0 & l_1 \cdot s\theta_1 + d_2 \cdot c\theta_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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Problem 3: Program Forward Kinematics for Puma 560 Robots using Matlab

Matlab code:

```
%Parameter of Manipulator
th1 = pi/4;
th2 = pi/3;
th3 = pi/4;
th4 = pi/3;
th5 = pi/4;
th6 = pi/6;

a2 = 1; a3 = 0.3; d3 = 0.5; d4 = 1;
P6_T = [0;0;0.2];

%D-H parameters
syms a1 a d th,

T = [cos(th) -sin(th) 0 a;
    sin(th)*cos(a1) cos(th)*cos(a1) -sin(a1) -sin(a1)*d;
    sin(th)*sin(a1) cos(th)*sin(a1) cos(a1) cos(a1)*d;
    0 0 0 1];

T01 = vpa(subs(T,{a1,a,d,th},{[0,0,0,th1]}),2);
T12 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th2]}),2);
T23 = vpa(subs(T,{a1,a,d,th},{[0,a2,d3,th3]}),2);
T34 = vpa(subs(T,{a1,a,d,th},{[-pi/2,a3,d4,th4]}),2);
T45 = vpa(subs(T,{a1,a,d,th},{[pi/2,0,0,th5]}),2);
T56 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th6]}),2);

T06 = vpa(T01*T12*T23*T34*T45*T56,2)
```

The output of Matlab: T06

```
>> manipulator_2

T06 =

[  0.16,  0.5, -0.85,  -0.74]
[ -0.95, 0.32, 0.015, -0.031]
[  0.28,  0.8,  0.52,   -0.9]
[     0,    0,     0,    1.0]
```