Mini project - Calculations

1. Transformation Matrix for a Single Link

In[1]:=
```
A[a_, alpha_, d_, theta_] :=
 {{Cos[theta], -Sin[theta] Cos[alpha],  Sin[theta] Sin[alpha], a Cos[theta]},
  {Sin[theta],  Cos[theta] Cos[alpha], -Cos[theta] Sin[alpha], a Sin[theta]},
  {0,           Sin[alpha],             Cos[alpha],            d},
  {0,           0,                      0,                     1}}
```

2. Get Transformation Matrices for all Links

In[2]:=
```
A1 = A[1.3, 90 Degree, 9.5, θ1];
A2 = A[12, 0 Degree, 0, θ2];
A3 = A[12, 0 Degree, 0, θ3];
A4 = A[11, 0 Degree, 0, θ4];

T = Simplify[A1.A2.A3.A4];

MatrixForm[T]
```

Out[7]//MatrixForm=

$$\begin{pmatrix} \cos(\theta_1)\cos(\theta_2+\theta_3+\theta_4) & -\cos(\theta_1)\sin(\theta_2+\theta_3+\theta_4) & \sin(\theta_1) & 12.\cos(\theta_1)\left(0.108333+1.\cos[\right. \\ \cos(\theta_2+\theta_3+\theta_4)\sin(\theta_1) & -\sin(\theta_1)\sin(\theta_2+\theta_3+\theta_4) & -\cos(\theta_1) & 12.\left(0.108333+1.\cos(\theta_2)+1.\right. \\ \sin(\theta_2+\theta_3+\theta_4) & \cos(\theta_2+\theta_3+\theta_4) & 0. & 9.5+12.\sin(\theta_2)+1 \\ 0 & 0 & 0 & \end{pmatrix}$$

3. Manipulator Jacobian

>> Define the initial z-axis and position

In[8]:=
```
t0 = {0, 0, 0};
z0 = {0, 0, 1};
```

>> Calculate the intermediate transformations

($H_0^2 \rightarrow$ A12, $H_0^3 \rightarrow$ A123)

In[10]:=
```
A12 = Simplify[A1.A2];
A123 = Simplify[A12.A3];
```

>> Extract required vectors from transformation matrices

($t_1^0 \rightarrow$ t1 , $z_1^0 \rightarrow$ z1 , $t_2^0 \rightarrow$ t2 , $z_2^0 \rightarrow$ z2 , $t_3^0 \rightarrow$ t3 , $z_3^0 \rightarrow$ z3 , $t_4^0 \rightarrow$ t4)

In[12]:=
```
t1 = A1[[1 ;; 3, 4]];
z1 = A1[[1 ;; 3, 3]];

t2 = A12[[1 ;; 3, 4]];
z2 = A12[[1 ;; 3, 3]];

t3 = A123[[1 ;; 3, 4]];
z3 = A123[[1 ;; 3, 3]];

t4 = T[[1 ;; 3, 4]];

column1 = MatrixForm[Join[Simplify[z0 × (t4 - t0)], z0]]
column2 = MatrixForm[Join[Simplify[z1 × (t4 - t1)], z1]]
column3 = MatrixForm[Join[Simplify[z2 × (t4 - t2)], z2]]
column4 = MatrixForm[Join[Simplify[z3 × (t4 - t3)], z3]]
```

Out[19]//MatrixForm=

$$\begin{pmatrix} \left(-1.3 - 12.\cos[\theta_2] - 12.\cos[\theta_2+\theta_3] - 11.\cos[\theta_2+\theta_3+\theta_4]\right)\sin[\theta_1] \\ \cos[\theta_1]\left(1.3 + 12.\cos[\theta_2] + 12.\cos[\theta_2+\theta_3] + 11.\cos[\theta_2+\theta_3+\theta_4]\right) \\ 0. \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

Out[20]//MatrixForm=

$$\begin{pmatrix} \cos[\theta_1]\left(-12.\sin[\theta_2] - 12.\sin[\theta_2+\theta_3] - 11.\sin[\theta_2+\theta_3+\theta_4]\right) \\ \sin[\theta_1]\left(-12.\sin[\theta_2] - 12.\sin[\theta_2+\theta_3] - 11.\sin[\theta_2+\theta_3+\theta_4]\right) \\ 12.\cos[\theta_2] + 12.\cos[\theta_2+\theta_3] + 11.\cos[\theta_2+\theta_3+\theta_4] \\ \sin[\theta_1] \\ -\cos[\theta_1] \\ 0 \end{pmatrix}$$

Out[21]//MatrixForm=

$$\begin{pmatrix} \cos[\theta_1]\left(-12.\sin[\theta_2+\theta_3] - 11.\sin[\theta_2+\theta_3+\theta_4]\right) \\ \sin[\theta_1]\left(-12.\sin[\theta_2+\theta_3] - 11.\sin[\theta_2+\theta_3+\theta_4]\right) \\ 12.\cos[\theta_2+\theta_3] + 11.\cos[\theta_2+\theta_3+\theta_4] \\ \sin[\theta_1] \\ -\cos[\theta_1] \\ 0. \end{pmatrix}$$

Out[22]//MatrixForm=

$$\begin{pmatrix} -11.\cos[\theta_1]\sin[\theta_2+\theta_3+\theta_4] \\ -11.\sin[\theta_1]\sin[\theta_2+\theta_3+\theta_4] \\ 11.\cos[\theta_2+\theta_3+\theta_4] \\ \sin[\theta_1] \\ -\cos[\theta_1] \\ 0. \end{pmatrix}$$