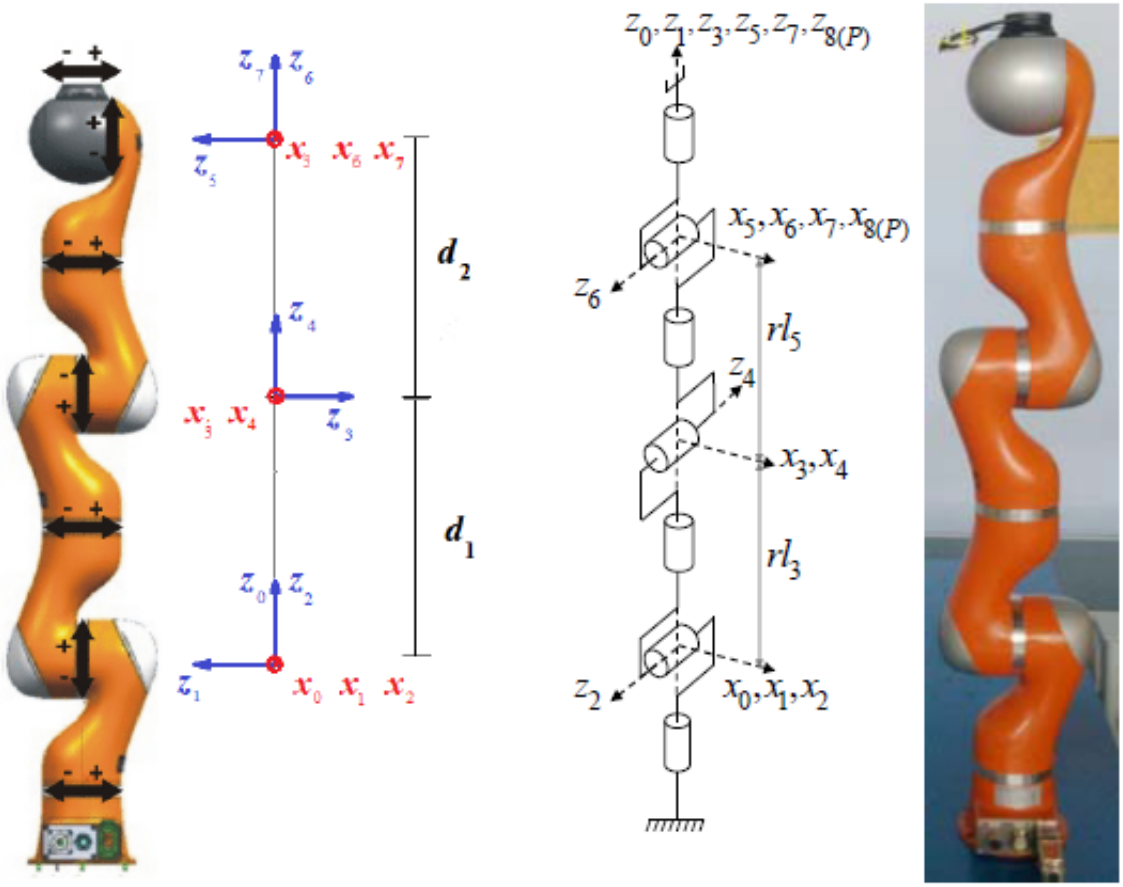
MSA model of KUKA_iiwa robot manipulator:



Link stiffness model:

$$K_{links} = \begin{bmatrix} K_{11}^{1,2} & K_{12}^{1,2} & 0 & 0 & 0 & 0 & 0 & 0 \\ K_{21}^{1,2} & K_{22}^{1,2} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & K_{11}^{12} & K_{12}^{12} & 0 & 0 & 0 & 0 \\ 0 & 0 & K_{21}^{12} & K_{22}^{12} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & .... & .... & 0 & 0 \\ 0 & 0 & 0 & 0 & .... & .... & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & K_{11}^{11,12} & K_{12}^{11,12} \\ 0 & 0 & 0 & 0 & 0 & 0 & K_{21}^{11,12} & K_{22}^{11,12} \end{bmatrix}$$

Stiffness matrices of the links with regular shape

Basic expression for stiffness model

$$\begin{bmatrix} \mathbf{W}_1 \\ \mathbf{W}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{K}_{11} & \mathbf{K}_{12} \\ \mathbf{K}_{21} & \mathbf{K}_{22} \end{bmatrix}_{12\times 12} \cdot \begin{bmatrix} \Delta\mathbf{t}_1 \\ \Delta\mathbf{t}_2 \end{bmatrix}$$

$$\mathbf{K}_{12} = \mathbf{K}_{21}^{T} = \begin{bmatrix} \frac{-E\cdot S}{L} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{-12\cdot E\cdot Iz}{L^3} & 0 & 0 & 0 & \frac{6\cdot E\cdot Iz}{L^2} \\ 0 & 0 & \frac{-12\cdot E\cdot Iy}{L^3} & 0 & \frac{-6\cdot E\cdot Iy}{L^2} & 0 \\ 0 & 0 & 0 & \frac{-G\cdot J}{L} & 0 & 0 \\ 0 & 0 & \frac{6\cdot E\cdot Iy}{L^2} & 0 & \frac{2\cdot E\cdot Iy}{L} & 0 \\ 0 & \frac{-6\cdot E\cdot Iz}{L^2} & 0 & 0 & 0 & \frac{2\cdot E\cdot Iz}{L} \end{bmatrix}$$

$$\mathbf{K}_{11} = \begin{bmatrix} \frac{E\cdot S}{L} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{12\cdot E\cdot Iz}{L^3} & 0 & 0 & 0 & \frac{6\cdot E\cdot I}{L^2} \\ 0 & 0 & \frac{12\cdot E\cdot Iy}{L^3} & 0 & \frac{-6\cdot E\cdot Iy}{L^2} & 0 \\ 0 & 0 & 0 & \frac{G\cdot J}{L} & 0 & 0 \\ 0 & 0 & \frac{-6\cdot E\cdot Iy}{L^2} & 0 & \frac{4\cdot E\cdot Iy}{L} & 0 \\ 0 & \frac{6\cdot E\cdot Iz}{L^2} & 0 & 0 & 0 & \frac{4\cdot E\cdot Iz}{L} \end{bmatrix} \quad \mathbf{K}_{22} = \begin{bmatrix} \frac{E\cdot S}{L} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{12\cdot E\cdot Iz}{L^3} & 0 & 0 & 0 & \frac{-6\cdot E\cdot I}{L^2} \\ 0 & 0 & \frac{12\cdot E\cdot Iy}{L^3} & 0 & \frac{6\cdot E\cdot Iy}{L^2} & 0 \\ 0 & 0 & 0 & \frac{G\cdot J}{L} & 0 & 0 \\ 0 & 0 & \frac{6\cdot E\cdot Iy}{L^2} & 0 & \frac{4\cdot E\cdot Iy}{L} & 0 \\ 0 & \frac{-6\cdot E\cdot Iz}{L^2} & 0 & 0 & 0 & \frac{4\cdot E\cdot Iz}{L} \end{bmatrix}$$

For the joints:

We have seven elastic joints, three rotations about x, three rotations about z and an elastic support:

1. elastic support <0,1>:

$$\lambda^{r}_{*01} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \quad \lambda^{e}_{*01} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\lambda^{r}_{*01} \cdot \Delta t_1 = 0_{5\times 1} \qquad K_e \cdot \lambda^{e}_{*01} \cdot \Delta t_1 - \lambda^{e}_{*01} \cdot W_1 = 0$$

2. elastic joints with rotation about x-axis <2,3> <6,7> <10,11>:

$$\lambda^{r}_{*ij} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \lambda^{e}_{*ij} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} \lambda^e_{*ij} & 0_{6\times6} & K^e_{ij}\cdot\lambda^e_{*ij} & -K^e_{ij}\cdot\lambda^e_{*ij} \\ I_{6\times6} & I_{6\times6} & 0_{6\times6} & 0_{6\times6} \\ 0_{6\times6} & 0_{6\times6} & \lambda^r_{*ij} & -\lambda^r_{*ij} \end{bmatrix} \begin{bmatrix} W_i \\ W_j \\ \Delta_i \\ \Delta_j \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

3. elastic joints with rotations about the z-axis <4,5> <8,9> <12,13>:

$$\lambda^r_{*ij} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \quad \lambda^e_{*ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \lambda^e_{*ij} & 0_{6\times6} & K^e_{ij}\cdot\lambda^e_{*ij} & -K^e_{ij}\cdot\lambda^e_{*ij} \\ I_{6\times6} & I_{6\times6} & 0_{6\times6} & 0_{6\times6} \\ 0_{6\times6} & 0_{6\times6} & \lambda^r_{*ij} & -\lambda^r_{*ij} \end{bmatrix} \begin{bmatrix} W_i \\ W_j \\ \Delta_i \\ \Delta_j \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

4.Aggregated model:

$$\begin{bmatrix} -I_{84\times84} & K_{links} \\ 0_{35\times84} & A_{agr} \\ B_{agr} & 0_{36\times84} \\ C_{agr} & D_{agr} \\ E_{agr} & 0_{6\times84} \end{bmatrix} \begin{bmatrix} W_{agr} \\ \Delta t_{agr} \end{bmatrix} = \begin{bmatrix} 0_{168\times1} \\ W_e 0 \end{bmatrix}$$

with:

$$A_{agr} = \begin{bmatrix} \lambda^r_{*01} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \lambda^r_{*23} & -\lambda^r_{*23} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \lambda^r_{*45} & -\lambda^r_{*45} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \lambda^r_{*67} & -\lambda^r_{*67} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda^r_{*89} & -\lambda^r_{*89} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda^r_{*1011} & -\lambda^r_{*1011} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \lambda^r_{*12e} & -\lambda^r_{*12e} \end{bmatrix} \quad B_{agr} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$
\begin{bmatrix}
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
0 & 0 \\
12e & 0
\end{bmatrix}
D_{agr} =
\begin{bmatrix}
K_{01}^{e} \cdot \lambda_{*01}^{e} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & K_{23}^{e} \cdot \lambda_{*23}^{e} & -K_{23}^{e} \cdot \lambda_{*23}^{e} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & K_{45}^{e} \cdot \lambda_{*45}^{e} & -K_{45}^{e} \cdot \lambda_{*45}^{e} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & K_{67}^{e} \cdot \lambda_{*67}^{e} & -K_{67}^{e} \cdot \lambda_{*67}^{e} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & K_{89}^{e} \cdot \lambda_{*89}^{e} & -K_{89}^{e} \cdot \lambda_{*89}^{e} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

```
clear all, clc

robot.Tbase = eye(4);
robot.Ttool = eye(4);
q1 = 0;
q2 = 0;
q3 = 0;
q4 = 0;
q5 = 0;
q6 = 0;
q7 = 0;
% Actuator stiff
robot.Kact=1e6;

% material and shape parameters
E = 70 *10e9; % Young's modulus
G = 25.5*10e9; % shear modulus
d_1 = 10*10e-3;

% we have four type of links corresponding to four lengths
robot.L(1) = 0.21;
robot.L(2) = 0.2;
robot.L(3) = 0.126;
robot.L(4) = 0.05;

% for cylinder
S = pi*d_1^2/4;
Iy = pi*d_1^4/64;
Iz = pi*d_1^4/64;
J = Iy + Iz;

%% links stiffness models
% LINK TYPE 1
robot.k11_1 = [E*S/robot.L(1) 0                   0                  0           0
    0           12*E*Iz/robot.L(1)^3  0                  0           0                  6*E*Iz/r
    0           0                   12*E*Iy/robot.L(1)^3 0           -6*E*Iy/robot.L(1)^2 0;
    0           0                   0                  G*J/robot.L(1) 0                  0;
    0           0                   -6*E*Iy/robot.L(1)^2 0           4*E*Iy/robot.L(1)      0;
    0           6*E*Iz/robot.L(1)^2   0                  0           0                  4*E*Iz/r

robot.k12_1 = [-E*S/robot.L(1) 0                    0                  0           0
    0            -12*E*Iz/robot.L(1)^3  0                  0           0                  6*E*
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    0           0                   -12*E*Iy/robot.L(1)^3 0           -6*E*Iy/robot.L(1)^2 0
    0           0                   0                  -G*J/robot.L(1) 0                 0;
    0           0                   6*E*Iy/robot.L(1)^2   0           2*E*Iy/robot.L(1)
    0           -6*E*Iz/robot.L(1)^2    0                 0           0                 2*E*

robot.k21_1 = [-E*S/robot.L(1) 0                   0                   0           0
    0            -12*E*Iz/robot.L(1)^3  0                   0           0                 -6*E
    0            0                   -12*E*Iy/robot.L(1)^3 0           6*E*Iy/robot.L(1)^2  0
    0            0                   0                  -G*J/robot.L(1) 0                 0;
    0            0                   -6*E*Iy/robot.L(1)^2  0           2*E*Iy/robot.L(1)    0
    0            6*E*Iz/robot.L(1)^2    0                 0           0                 2*E*

robot.k22_1 = [E*S/robot.L(1) 0                   0                   0           0
    0           12*E*Iz/robot.L(1)^3   0                   0           0                 -6*E*I
    0           0                   12*E*Iy/robot.L(1)^3 0           6*E*Iy/robot.L(1)^2  0;
    0           0                   0                  G*J/robot.L(1)  0                 0;
    0           0                   6*E*Iy/robot.L(1)^2  0           4*E*Iy/robot.L(1)    0;
    0           -6*E*Iz/robot.L(1)^2   0                   0           0                 4*E*Iz


% LINK TYPE 2
robot.k11_2 = [E*S/robot.L(2) 0                   0                   0           0
    0           12*E*Iz/robot.L(2)^3  0                   0           0                 6*E*Iz/r
    0           0                   12*E*Iy/robot.L(2)^3 0           -6*E*Iy/robot.L(2)^2 0;
    0           0                   0                  G*J/robot.L(2) 0                 0;
    0           0                   -6*E*Iy/robot.L(2)^2 0           4*E*Iy/robot.L(2)      0;
    0           6*E*Iz/robot.L(2)^2   0                   0           0                 4*E*Iz/r

robot.k12_2 = [-E*S/robot.L(2) 0                   0                   0           0
    0            -12*E*Iz/robot.L(2)^3  0                   0           0                 6*E*
    0           0                   -12*E*Iy/robot.L(2)^3 0           -6*E*Iy/robot.L(2)^2 0
    0           0                   0                  -G*J/robot.L(2) 0                 0;
    0           0                   6*E*Iy/robot.L(2)^2   0           2*E*Iy/robot.L(2)
    0           -6*E*Iz/robot.L(2)^2    0                 0           0                 2*E*

robot.k21_2 = [-E*S/robot.L(2) 0                   0                   0           0
    0            -12*E*Iz/robot.L(2)^3  0                   0           0                 -6*E
    0            0                   -12*E*Iy/robot.L(2)^3 0           6*E*Iy/robot.L(2)^2  0
    0            0                   0                  -G*J/robot.L(2) 0                 0;
    0            0                   -6*E*Iy/robot.L(2)^2  0           2*E*Iy/robot.L(2)    0
    0            6*E*Iz/robot.L(2)^2    0                 0           0                 2*E*

robot.k22_2 = [E*S/robot.L(2) 0                   0                   0           0
    0           12*E*Iz/robot.L(2)^3   0                   0           0                 -6*E*I
    0           0                   12*E*Iy/robot.L(2)^3 0           6*E*Iy/robot.L(2)^2  0;
    0           0                   0                  G*J/robot.L(2)  0                 0;
    0           0                   6*E*Iy/robot.L(2)^2  0           4*E*Iy/robot.L(2)    0;
    0           -6*E*Iz/robot.L(2)^2   0                   0           0                 4*E*Iz

% LINK TYPE 3
robot.k11_3 = [E*S/robot.L(3) 0                   0                   0           0
    0           12*E*Iz/robot.L(3)^3  0                   0           0                 6*E*Iz/r
    0           0                   12*E*Iy/robot.L(3)^3 0           -6*E*Iy/robot.L(3)^2 0;
    0           0                   0                  G*J/robot.L(3) 0                 0;
    0           0                   -6*E*Iy/robot.L(3)^2 0           4*E*Iy/robot.L(3)      0;
    0           6*E*Iz/robot.L(3)^2   0                   0           0                 4*E*Iz/r

robot.k12_3 = [-E*S/robot.L(3) 0                   0                   0           0
    0            -12*E*Iz/robot.L(3)^3  0                   0           0                 6*E*
    0           0                   -12*E*Iy/robot.L(3)^3 0           -6*E*Iy/robot.L(3)^2 0
    0           0                   0                  -G*J/robot.L(3) 0                 0;
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    0           0                   6*E*Iy/robot.L(3)^2   0           2*E*Iy/robot.L(3)
    0           -6*E*Iz/robot.L(3)^2    0                 0           0                 2*E*

robot.k21_3 = [-E*S/robot.L(3) 0                   0                 0           0
    0            -12*E*Iz/robot.L(3)^3  0                 0           0                 -6*E
    0            0                   -12*E*Iy/robot.L(3)^3 0           6*E*Iy/robot.L(3)^2  0
    0            0                   0                 -G*J/robot.L(3) 0                 0;
    0            0                   -6*E*Iy/robot.L(3)^2  0           2*E*Iy/robot.L(3)    0
    0            6*E*Iz/robot.L(3)^2    0                 0           0                 2*E*

robot.k22_3 = [E*S/robot.L(3) 0                   0                 0           0
    0           12*E*Iz/robot.L(3)^3   0                 0           0                 -6*E*I
    0           0                   12*E*Iy/robot.L(3)^3 0           6*E*Iy/robot.L(3)^2  0;
    0           0                   0                 G*J/robot.L(3)  0                 0;
    0           0                   6*E*Iy/robot.L(3)^2  0           4*E*Iy/robot.L(3)    0;
    0           -6*E*Iz/robot.L(3)^2   0                 0           0                 4*E*Iz

% LINK TYPE 4
robot.k11_4 = [E*S/robot.L(4) 0                   0                 0           0
    0           12*E*Iz/robot.L(4)^3  0                 0           0                 6*E*Iz/r
    0           0                   12*E*Iy/robot.L(4)^3 0           -6*E*Iy/robot.L(4)^2 0;
    0           0                   0                 G*J/robot.L(4) 0                 0;
    0           0                   -6*E*Iy/robot.L(4)^2 0           4*E*Iy/robot.L(4)      0;
    0           6*E*Iz/robot.L(4)^2   0                 0           0                 4*E*Iz/r

robot.k12_4 = [-E*S/robot.L(4) 0                   0                 0           0
    0            -12*E*Iz/robot.L(4)^3  0                 0           0                 6*E*
    0           0                   -12*E*Iy/robot.L(4)^3 0           -6*E*Iy/robot.L(4)^2 0
    0           0                   0                 -G*J/robot.L(4) 0                 0;
    0           0                   6*E*Iy/robot.L(4)^2   0           2*E*Iy/robot.L(4)
    0           -6*E*Iz/robot.L(4)^2    0                 0           0                 2*E*

robot.k21_4 = [-E*S/robot.L(4) 0                   0                 0           0
    0            -12*E*Iz/robot.L(4)^3  0                 0           0                 -6*E
    0            0                   -12*E*Iy/robot.L(4)^3 0           6*E*Iy/robot.L(4)^2  0
    0            0                   0                 -G*J/robot.L(4) 0                 0;
    0            0                   -6*E*Iy/robot.L(4)^2  0           2*E*Iy/robot.L(4)    0
    0            6*E*Iz/robot.L(4)^2    0                 0           0                 2*E*

robot.k22_4 = [E*S/robot.L(4) 0                   0                 0           0
    0           12*E*Iz/robot.L(4)^3   0                 0           0                 -6*E*I
    0           0                   12*E*Iy/robot.L(4)^3 0           6*E*Iy/robot.L(4)^2  0;
    0           0                   0                 G*J/robot.L(4)  0                 0;
    0           0                   6*E*Iy/robot.L(4)^2  0           4*E*Iy/robot.L(4)    0;
    0           -6*E*Iz/robot.L(4)^2   0                 0           0                 4*E*Iz

%% rotation matrices for K_global
theta = q1;
Rl1= [cos(theta) -sin(theta) 0 0 0 0;
    sin(theta) cos(theta) 0 0 0 0;
    0 0 1 0 0 0;
    0 0 0 cos(theta) -sin(theta) 0;
    0 0 0 sin(theta) cos(theta) 0;
    0 0 0 0 0 1];

theta = q2;
Rl2 = Rl1*[1 0 0 0 0 0;
    0 cos(theta) -sin(theta) 0 0 0;
    0 sin(theta) cos(theta) 0 0 0;
    0 0 0 1 0 0;
    0 0 0 0 cos(theta) -sin(theta);
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```
    0 0 0 0 sin(theta) cos(theta)];

theta = q3;
Rl3= Rl2*[cos(theta) -sin(theta) 0 0 0 0;
    sin(theta) cos(theta) 0 0 0 0;
    0 0 1 0 0 0;
    0 0 0 cos(theta) -sin(theta) 0;
    0 0 0 sin(theta) cos(theta) 0;
    0 0 0 0 0 1];

theta = q4;
Rl4 = Rl3*[1 0 0 0 0 0;
    0 cos(theta) -sin(theta) 0 0 0;
    0 sin(theta) cos(theta) 0 0 0;
    0 0 0 1 0 0;
    0 0 0 0 cos(theta) -sin(theta);
    0 0 0 0 sin(theta) cos(theta)];

theta = q5;
Rl5= Rl4*[cos(theta) -sin(theta) 0 0 0 0;
    sin(theta) cos(theta) 0 0 0 0;
    0 0 1 0 0 0;
    0 0 0 cos(theta) -sin(theta) 0;
    0 0 0 sin(theta) cos(theta) 0;
    0 0 0 0 0 1];

theta = q6;
Rl6 = Rl5*[1 0 0 0 0 0;
    0 cos(theta) -sin(theta) 0 0 0;
    0 sin(theta) cos(theta) 0 0 0;
    0 0 0 1 0 0;
    0 0 0 0 cos(theta) -sin(theta);
    0 0 0 0 sin(theta) cos(theta)];

theta = q7;
Rl7= Rl6*[cos(theta) -sin(theta) 0 0 0 0;
    sin(theta) cos(theta) 0 0 0 0;
    0 0 1 0 0 0;
    0 0 0 cos(theta) -sin(theta) 0;
    0 0 0 sin(theta) cos(theta) 0;
    0 0 0 0 0 1];

%% global stiffness parameters
k11_12 = Rl1 * robot.k11_1 * Rl1';
k12_12 = Rl1 * robot.k12_1 * Rl1';
k21_12 = Rl1 * robot.k21_1 * Rl1';
k22_12 = Rl1 * robot.k22_1 * Rl1';

k11_34 = Rl2 * robot.k11_1 * Rl2';
k12_34 = Rl2 * robot.k12_1 * Rl2';
k21_34 = Rl2 * robot.k21_1 * Rl2';
k22_34 = Rl2 * robot.k22_1 * Rl2';

k11_56 = Rl3 * robot.k11_1 * Rl3';
k12_56 = Rl3 * robot.k12_1 * Rl3';
k21_56 = Rl3 * robot.k21_1 * Rl3';
k22_56 = Rl3 * robot.k22_1 * Rl3';

k11_78 = Rl4 * robot.k11_2 * Rl4';
k12_78 = Rl4 * robot.k12_2 * Rl4';
k21_78 = Rl4 * robot.k21_2 * Rl4';
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k22_78 = Rl4 * robot.k22_2 * Rl4';

k11_910 = Rl5 * robot.k11_2 * Rl5';
k12_910 = Rl5 * robot.k12_2 * Rl5';
k21_910 = Rl5 * robot.k21_2 * Rl5';
k22_910 = Rl5 * robot.k22_2 * Rl5';

k11_1112 = Rl6 * robot.k11_3 * Rl6';
k12_1112 = Rl6 * robot.k12_3 * Rl6';
k21_1112 = Rl6 * robot.k21_3 * Rl6';
k22_1112 = Rl6 * robot.k22_3 * Rl6';

k11_13e = Rl7 * robot.k11_4 * Rl7';
k12_13e = Rl7 * robot.k12_4 * Rl7';
k21_13e = Rl7 * robot.k21_4 * Rl7';
k22_13e = Rl7 * robot.k22_4 * Rl7';

%% Klink global
Klinks = [k11_12 k12_12 zeros(6,72);
        k21_12 k22_12 zeros(6,72);
        zeros(6,12) k11_34 k12_34 zeros(6,60);
        zeros(6,12) k21_34 k22_34 zeros(6,60);
        zeros(6,24) k11_56 k12_56 zeros(6,48);
        zeros(6,24) k21_56 k22_56 zeros(6,48);
        zeros(6,36) k11_78 k12_78 zeros(6,36);
        zeros(6,36) k21_78 k22_78 zeros(6,36);
        zeros(6,48) k11_910 k12_910 zeros(6,24);
        zeros(6,48) k21_910 k22_910 zeros(6,24);
        zeros(6,60) k11_1112 k12_1112 zeros(6,12);
        zeros(6,60) k21_1112 k22_1112 zeros(6,12)
        zeros(6,72) k11_13e k12_13e;
        zeros(6,72) k21_13e k22_13e];

%% joints constraints
Lr01 = [1 0 0 0 0 0;
        0 1 0 0 0 0;
        0 0 1 0 0 0;
        0 0 0 1 0 0;
        0 0 0 0 1 0];
Le01 = [0 0 0 0 0 1];

Lr23 = [1 0 0 0 0 0;
        0 1 0 0 0 0;
        0 0 1 0 0 0;
        0 0 0 0 1 0;
        0 0 0 0 0 1];
Le23 = [0 0 0 1 0 0];

%% aggregated matrices
Aagr = [Lr01 zeros(5,72) zeros(5,6);
        zeros(5,6) Lr23 -Lr23 zeros(5,60) zeros(5,6);
        zeros(5,18) Lr01 -Lr01 zeros(5,48) zeros(5,6);
        zeros(5,30) Lr23 -Lr23 zeros(5,36) zeros(5,6);
        zeros(5,42) Lr01 -Lr01 zeros(5,24) zeros(5,6);
        zeros(5,54) Lr23 -Lr23 zeros(5,12) zeros(5,6);
        zeros(5,66) Lr01 -Lr01 zeros(5,6)];

Bagr = [zeros(6,6) eye(6) eye(6) zeros(6,60) zeros(6,6);
        zeros(6,18) eye(6) eye(6) zeros(6,48) zeros(6,6);
        zeros(6,30) eye(6) eye(6) zeros(6,36) zeros(6,6);
        zeros(6,42) eye(6) eye(6) zeros(6,24) zeros(6,6);
```

```
        zeros(6,54) eye(6) eye(6) zeros(6,12) zeros(6,6);
        zeros(6,66) eye(6) eye(6) zeros(6,6)];

Cagr = [Le01 zeros(1,72) zeros(1,6);
        zeros(1,12) Le23 zeros(1,60) zeros(1,6);
        zeros(1,24) Le01 zeros(1,48) zeros(1,6);
        zeros(1,36) Le23 zeros(1,36) zeros(1,6);
        zeros(1,48) Le01 zeros(1,24) zeros(1,6);
        zeros(1,60) Le23 zeros(1,12) zeros(1,6);
        zeros(1,72) Le01 zeros(1,6)];

Dagr = [robot.Kact*Le01 zeros(1,72) zeros(1,6);
        zeros(1,6) robot.Kact*Le23 -robot.Kact*Le23 zeros(1,60) zeros(1,6);
        zeros(1,18) robot.Kact*Le01 -robot.Kact*Le01 zeros(1,48) zeros(1,6);
        zeros(1,30) robot.Kact*Le23 -robot.Kact*Le23 zeros(1,36) zeros(1,6);
        zeros(1,42) robot.Kact*Le01 -robot.Kact*Le01 zeros(1,24) zeros(1,6);
        zeros(1,54) robot.Kact*Le23 -robot.Kact*Le23 zeros(1,12) zeros(1,6);
        zeros(1,66) robot.Kact*Le01 -robot.Kact*Le01 zeros(1,6)];

Eagr = [zeros(6,78) eye(6)];
Fagr = [zeros(6,84)];

Sagr = [-eye(84);zeros(35,84);Bagr;Cagr];
Kagr = [Klinks;Aagr;zeros(36,84);Dagr];

fm=[Sagr Kagr;
    Eagr Fagr];

A = fm(1:162,1:162);
B = fm(1:162,163:168);
C = fm(163:168,1:162);
D = fm(163:168,163:168);

% Final formula for Kc
Kc = D - C*inv(A)*B
```

```
Kc = 6x6 double

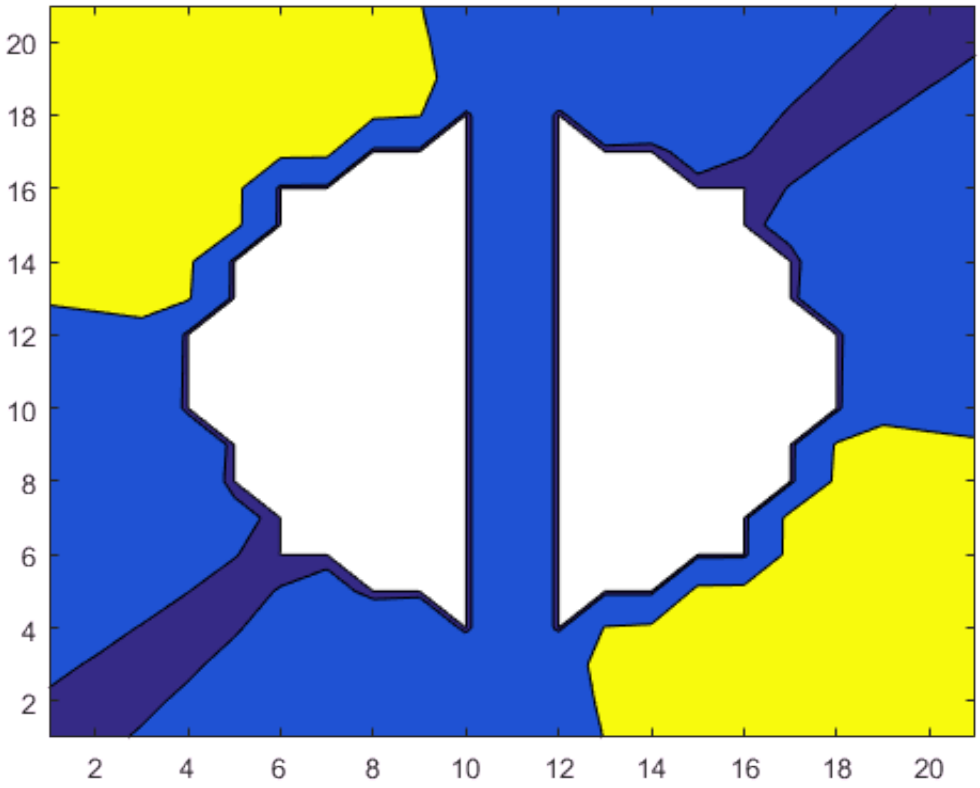
   1.0e+09 *
    4.5587         0         0         0         0         0
         0    0.0011         0         0         0    0.0001
         0         0    0.0235         0    0.0142         0
         0         0         0   -0.0004         0         0
         0         0    0.0142         0    0.0114         0
         0    0.0001         0         0         0   -0.0006
```

```
F  =[1000; 1000; 0; 0; 0; 0]
```

```
F = 6x1 double

        1000
        1000
           0
           0
           0
           0
```

```
%% functions that show deflection map
showDeflection(F, 'MSA')
```


20
18
16
14
12
10
8
6
4
2
2
4
6
8
10
12
14
16
18
20