Algorythm:

Foreward kinematics, for random joint and links valiues calculate the foreward kinematics:

```
for i = 1:10
algo_lab3
end
```

```
-------New System!---------
d1_val =
0.7920
a1_val =
0.2004
th2_val =
1.1372
a2_val =
0.6939
th3_val =
0.0453
d3_val =
0.2769
th4_val =
0.5531
d4_val =
0.1929

T04_val = 4×4
    0.3222   -0.1989   -0.9256    0.0572
    0.7876   -0.4862    0.3786    0.8075
   -0.5253   -0.8509         0    0.7920
         0         0         0    1.0000
T03 = 4×4
    0.3786         0   -0.9256    0.2357
    0.9256         0    0.3786    0.7345
         0   -1.0000         0    0.7920
         0         0         0    1.0000
P = 3×1
    0.0572
    0.8075
    0.7920
pw = 3×1
   -0.1785
    0.0730
         0
pa = 3×1
    0.2357
    0.7345
    0.7920

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.7920
d1_val =
0.7920
q2_ik =
1.1372
th2_val =
1.1372
```

```
q3_ik =
0.0453
th3_val =
0.0453

ans_2 = 2×1
    0.5531
   -0.5531
th4_val =
0.5531


-------New System!---------
d1_val =
0.2799
a1_val =
0.3442
th2_val =
0.7813
a2_val =
0.5954
th3_val =
0.9109
d3_val =
0.1637
th4_val =
0.2140
d4_val =
0.1540

T04_val = 4×4
   -0.1184    0.0257   -0.9926    0.4515
    0.9700   -0.2108   -0.1212    0.3808
   -0.2124   -0.9772         0    0.2799
         0         0         0    1.0000
T03 = 4×4
   -0.1212         0   -0.9926    0.6044
    0.9926         0   -0.1212    0.3994
         0   -1.0000         0    0.2799
         0         0         0    1.0000
P = 3×1
    0.4515
    0.3808
    0.2799
pw = 3×1
   -0.1528
   -0.0187
         0
pa = 3×1
    0.6044
    0.3994
    0.2799

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.2799
d1_val =
0.2799
q2_ik =
0.7813
th2_val =
```

```
0.7813
q3_ik =
0.9109
th3_val =
0.9109

ans_2 = 2×1
    0.2140
   -0.2140
th4_val =
0.2140


-------New System!---------
d1_val =
0.2005
a1_val =
0.1818
th2_val =
0.5613
a2_val =
0.3971
th3_val =
-0.9748
d3_val =
0.1990
th4_val =
-2.2141
d4_val =
0.1330

T04_val = 4×4
   -0.5493    0.7326    0.4019    0.6514
    0.2411   -0.3215    0.9157    0.5154
    0.8001    0.5999         0    0.2005
         0         0         0    1.0000
T03 = 4×4
    0.9157         0    0.4019    0.5979
   -0.4019         0    0.9157    0.3936
         0   -1.0000         0    0.2005
         0         0         0    1.0000
P = 3×1
    0.6514
    0.5154
    0.2005
pw = 3×1
    0.0534
    0.1218
         0
pa = 3×1
    0.5979
    0.3936
    0.2005

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.2005
d1_val =
0.2005
q2_ik =
0.5613
```

```
th2_val =
0.5613
q3_ik =
-0.9748
th3_val =
-0.9748

ans_2 = 2×1
    2.2141
    4.0690
th4_val =
-2.2141


-------New System!---------
d1_val =
0.8656
a1_val =
0.4363
th2_val =
1.3497
a2_val =
0.5180
th3_val =
0.2601
d3_val =
0.2631
th4_val =
2.3814
d4_val =
0.6933

T04_val = 4×4
    0.0282    0.0268   -0.9992   -0.4057
   -0.7242   -0.6885   -0.0389    0.4681
   -0.6891    0.7247         0    0.8656
         0         0         0    1.0000
T03 = 4×4
   -0.0389         0   -0.9992    0.2871
    0.9992         0   -0.0389    0.4951
         0   -1.0000         0    0.8656
         0         0         0    1.0000
P = 3×1
   -0.4057
    0.4681
    0.8656
pw = 3×1
   -0.6928
   -0.0270
         0
pa = 3×1
    0.2871
    0.4951
    0.8656

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.8656
d1_val =
0.8656
q2_ik =
```

```
1.3497
th2_val =
1.3497
q3_ik =
0.2601
th3_val =
0.2601

ans_2 = 2×1
    3.9018
    2.3814
th4_val =
2.3814


-------New System!---------
d1_val =
0.1005
a1_val =
0.6193
th2_val =
0.3536
a2_val =
0.6940
th3_val =
0.0870
d3_val =
0.1959
th4_val =
1.8934
d4_val =
0.2367

T04_val = 4×4
   -0.2868   -0.8578   -0.4265    1.0858
   -0.1352   -0.4045    0.9045    0.6316
   -0.9484    0.3171         0    0.1005
         0         0         0    1.0000
T03 = 4×4
    0.9045         0   -0.4265    1.1867
    0.4265         0    0.9045    0.4175
         0   -1.0000         0    0.1005
         0         0         0    1.0000
P = 3×1
    1.0858
    0.6316
    0.1005
pw = 3×1
   -0.1010
    0.2141
         0
pa = 3×1
    1.1867
    0.4175
    0.1005

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.1005
d1_val =
0.1005
```

```
q2_ik =
0.3536
th2_val =
0.3536
q3_ik =
0.0870
th3_val =
0.0870

ans_2 = 2×1
    4.3898
    1.8934
th4_val =
1.8934


-------New System!---------
d1_val =
0.5483
a1_val =
0.6405
th2_val =
0.2346
a2_val =
0.6071
th3_val =
0.7497
d3_val =
0.2172
th4_val =
-1.5913
d4_val =
0.4998

T04_val = 4×4
   -0.0114    0.5534   -0.8329    0.6338
   -0.0171    0.8327    0.5535    0.5380
    0.9998    0.0205         0    0.5483
         0         0         0    1.0000
T03 = 4×4
    0.5535         0   -0.8329    1.0501
    0.8329         0    0.5535    0.2613
         0   -1.0000         0    0.5483
         0         0         0    1.0000
P = 3×1
    0.6338
    0.5380
    0.5483
pw = 3×1
   -0.4163
    0.2767
         0
pa = 3×1
    1.0501
    0.2613
    0.5483

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.5483
d1_val =
```

```
0.5483
q2_ik =
0.2346
th2_val =
0.2346
q3_ik =
0.7497
th3_val =
0.7497

ans_2 = 2×1
    1.5913
    4.6919
th4_val =
-1.5913


-------New System!---------
d1_val =
0.1751
a1_val =
0.4756
th2_val =
0.5056
a2_val =
0.5379
th3_val =
1.2276
d3_val =
0.2965
th4_val =
1.6904
d4_val =
0.4489

T04_val = 4×4
    0.0193    0.1605   -0.9868    0.2106
   -0.1177   -0.9798   -0.1617    0.1400
   -0.9929    0.1193         0    0.1751
         0         0         0    1.0000
T03 = 4×4
   -0.1617         0   -0.9868    0.6536
    0.9868         0   -0.1617    0.2126
         0   -1.0000         0    0.1751
         0         0         0    1.0000
P = 3×1
    0.2106
    0.1400
    0.1751
pw = 3×1
   -0.4430
   -0.0726
         0
pa = 3×1
    0.6536
    0.2126
    0.1751

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.1751
```

```
d1_val =
0.1751
q2_ik =
0.5056
th2_val =
0.5056
q3_ik =
1.2276
th3_val =
1.2276

ans_2 = 2×1
    1.6904
    4.5928
th4_val =
1.6904


-------New System!---------
d1_val =
0.9355
a1_val =
0.4481
th2_val =
-1.5174
a2_val =
0.1725
th3_val =
1.1395
d3_val =
0.1969
th4_val =
2.1668
d4_val =
0.2256

T04_val = 4×4
   -0.5217   -0.7692    0.3690    0.6132
    0.2071    0.3054    0.9294    0.2204
   -0.8276    0.5613         0    0.9355
         0         0         0    1.0000
T03 = 4×4
    0.9294         0    0.3690    0.5299
   -0.3690         0    0.9294    0.0107
         0   -1.0000         0    0.9355
         0         0         0    1.0000
P = 3×1
    0.6132
    0.2204
    0.9355
pw = 3×1
    0.0833
    0.2097
         0
pa = 3×1
    0.5299
    0.0107
    0.9355

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
```

```
0.9355
d1_val =
0.9355
q2_ik =
-1.5174
th2_val =
-1.5174
q3_ik =
1.1395
th3_val =
1.1395

ans_2 = 2×1
    4.1164
    2.1668
th4_val =
2.1668


-------New System!---------
d1_val =
0.5971
a1_val =
0.4779
th2_val =
-1.4703
a2_val =
0.4688
th3_val =
-0.4322
d3_val =
0.1099
th4_val =
-0.0655
d4_val =
0.2155

T04_val = 4×4
   -0.3250   -0.0213    0.9455    0.8326
   -0.9434   -0.0619   -0.3257   -0.5724
    0.0655   -0.9979         0    0.5971
         0         0         0    1.0000
T03 = 4×4
   -0.3257         0    0.9455    0.6289
   -0.9455         0   -0.3257   -0.5023
         0   -1.0000         0    0.5971
         0         0         0    1.0000
P = 3×1
    0.8326
   -0.5724
    0.5971
pw = 3×1
    0.2038
   -0.0702
         0
pa = 3×1
    0.6289
   -0.5023
    0.5971

ans_s = struct with fields:
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
```

```
q1_ik =
0.5971
d1_val =
0.5971
q2_ik =
-1.4703
th2_val =
-1.4703
q3_ik =
-0.4322
th3_val =
-0.4322

ans_2 = 2×1
    0.0655
   -0.0655
th4_val =
-0.0655


-------New System!---------
d1_val =
0.2108
a1_val =
0.2233
th2_val =
-1.1105
a2_val =
0.2134
th3_val =
-1.4368
d3_val =
0.2270
th4_val =
-1.3706
d4_val =
0.4232

T04_val = 4×4
   -0.1648   -0.8120    0.5599    0.6822
   -0.1114   -0.5487   -0.8285   -0.7299
    0.9800   -0.1989         0    0.2108
         0         0         0    1.0000
T03 = 4×4
   -0.8285         0    0.5599    0.4452
   -0.5599         0   -0.8285   -0.3793
         0   -1.0000         0    0.2108
         0         0         0    1.0000
P = 3×1
    0.6822
   -0.7299
    0.2108
pw = 3×1
    0.2369
   -0.3506
         0
pa = 3×1
    0.4452
   -0.3793
    0.2108

ans_s = struct with fields:
```

```
    q1: [2×1 sym]
    q2: [2×1 sym]
    q3: [2×1 sym]
q1_ik =
0.2108
d1_val =
0.2108
q2_ik =
-1.1105
th2_val =
-1.1105
q3_ik =
-1.4368
th3_val =
-1.4368

ans_2 = 2×1
   -1.3706
    1.3706
th4_val =
-1.3706
```

```
function algo_lab3
% this script determines a Homogeneous Transformation matrix
clear
disp(' ')
disp(" ")
disp('-------New System!---------')
d1_val=random('Uniform',0.1,1)
a1_val=random('Uniform',0.1,0.7)
th2_val=random('Uniform',-pi/2,pi/2)
a2_val=random('Uniform',0.1,0.7)
th3_val=random("Uniform",-pi/2,pi/2)
d3_val=random('Uniform',0.1,0.3)
th4_val=random('Uniform',-pi,pi)
d4_val=random('Uniform',0.1,0.7)
disp(" ")
A1=mA(0,d1_val,a1_val,0);
A2=mA(th2_val,0,a2_val,0);
A3=mA(th3_val,0,0,sym(-pi/2));
A32=mA(0,d3_val,0,0);
A4=mA(th4_val,d4_val,0,0);

T04_val=double(A1*A2*A3*A32*A4)

T03=double(A1*A2*A3*A32)

P=T04_val(1:3,4)
pw=T04_val(1:3,3)*d4_val


pa=P-pw %same as T03u
```

```
%
% T04n=subs(T04,{d1,a1,th2,a2,th3,d3,th4,d4},{d1_val,a1_val,th2_val,a2_val, ...
%     th3_val,d3_val,d3_val,th4_val,d4_val})
%%
syms d1 a1 th2 a2 th3 th4 d3 d4 q1 q2 q3 q4 real

A1=mA(0,d1,a1,0);
A2=mA(th2,0,a2,0);
A3=mA(th3,0,0,sym(-pi/2));
A32=mA(0,d3,0,0);
A4=mA(th4,d4,0,0);
T03=A1*A2*A3*A32;
T03v=subs(T03,{d1,a1,th2,a2,th3,d3},{q1,a1_val,q2,a2_val,q3,d3_val});
disp(" ")
eq = pa==(T03v(1:3,4));
ans_s=(solve(eq,[q1,q2,q3]))
q1_ik=double(ans_s.q1(1))
d1_val
q2_ik=double(ans_s.q2(1))
th2_val
q3_ik=double(ans_s.q3(1))
th3_val

T04=A1*A2*A3*A32*A4;
T04v=subs(T04,{d1,a1,th2,a2,th3,d3,th4,d4},
{d1_val,a1_val,th2_val,a2_val,th3_val,d3_val,q4,d4_val});
eq2 = T04_val(3,2)==(T04v(3,2));
disp(" ")

ans_2=double(solve(eq2,q4))
th4_val
end
```