```
% MEC529 Matlab Midterm Problem 3 Question (a) and (b), IK for elbow manipulator Codes Created by Yongxin Guo
addpath('/Users/guoyongxin/Desktop/Assignment_Academics/Senior_Second semester/MEC529/Myfunctions');

close all
clear
clc
% assign configuration constants.
l0 = 0.4;
l1 = 0.4;
l2 = 0.3;
l3 = 0.05;
R0 = eye(3);
P0 = [0;l1+l2+l3;l0];
gst0 = [R0,P0;[0 0 0],1];
% create axis of motion.
axis1 = [0;0;1];
axis2 = [-1;0;0];
axis3 = [-1;0;0];
axis4 = [0;0;1];
axis5 = [-1;0;0];
axis6 = [0;1;0];
axis_joints = [axis1,axis2,axis3,axis4,axis5,axis6];
% create q_matrix.
q1 = [0;0;l0];
q2 = q1;
q3 = [0;l1;l0]; % q3 here is q2 in the homework figure.
q4 = [0;l1+l2;l0];
q5 = q4;
q6 = q4; % q4 here is q3 in the homework figure.
q_joints = [q1,q2,q3,q4,q5,q6];
% create matrix for the type of joints
type_joints = ["R";"R";"R";"R";"R";"R"];

%---------------------------Question(a)---------------------------------
disp("***************************Question (a)******************************");
disp("***************************Starts here*******************************" + newline);
% given transformation matrix.
T_peg = [eye(3),[0.3;0.3;0];[0 0 0],1];
T_hole = [1 0 0 0.4;0 0 1 0.5;0 -1 0 0.1;0 0 0 1];
% feed T_peg and T_Hole into the elbow IK function and get the messages
% displayed and angles.
T_peg_IK_angles = getElbowManipIK(T_peg,gst0,axis_joints,q_joints,type_joints,"peg");
disp(T_peg_IK_angles);
disp("********************************************************************");
disp("********************************************************************");
disp(newline);
T_hole_IK_angles = getElbowManipIK(T_hole,gst0,axis_joints,q_joints,type_joints,"hole");
disp("In radians: ")
disp(T_hole_IK_angles);
disp("In degrees: ");
disp(T_hole_IK_angles*180/pi);

%---------------------------Question(b)---------------------------------
disp("***************************Question (b)******************************");
disp("***************************Starts here*******************************" + newline);
% select one soln at hole position from question (a) for the target
% configuration as the input of the computation of the joint rates.
% Note that the desired joint rates are [0;0;-0.01;0;0;0];
targetSolnNum = 7; % choose No.8 soln as the target config.
theta = T_hole_IK_angles(:,targetSolnNum); % assign to theta vector.
Vs = [0;0;-0.01;0;0;0]; % given joint rates.
Js = SpatialmanipJac(axis_joints,q_joints,type_joints,theta); %compute Spatial Jacobian.
thetadot = Js\Vs; % compute joint rate. Note that Js\Vs means inv(Js)*Vs.
disp("The elbow manipulator is in the following configuration (No." + num2str(targetSolnNum) + " config) when inserting the peg into the hole: ");
disp(theta);
disp("The desired joint angle rates for achieving the target end-effector speed of only -0.01 m/s along z-axis is: ");
disp(thetadot);
```

```
***************************Question (a)******************************
***************************Starts here*******************************

The given peg transformation matrix is shown below:
    1.0000         0         0    0.3000
         0    1.0000         0    0.3000
         0         0    1.0000         0
         0         0         0    1.0000


No.1 solution is:
    2.2655
    2.8889
    4.9758
   -1.5619
    0.6947
    1.5848


Its corresponding transformation matrix is:
    1.0000   -0.0000    0.0000    0.3000
    0.0000    1.0000    0.0000    0.3000
   -0.0000   -0.0000    1.0000         0
         0         0         0    1.0000


The corresponding difference with the given matrix is:
    1.0e-15 *
```

```
          0.2220    0.2220    0.8216    0.0555
          0.2776         0    0.0546    0.1110
          0.8604    0.0833    0.2220         0
               0         0         0         0
```

No.1 solution is valid!

No.2 solution is:
```
      2.2655
      2.8889
      4.9758
      1.5797
      2.4469
     -1.5568
```

Its corresponding transformation matrix is:
```
      1.0000   -0.0000    0.0000    0.3000
      0.0000    1.0000    0.0000    0.3000
     -0.0000   -0.0000    1.0000   -0.0000
           0         0         0    1.0000
```

The corresponding difference with the given matrix is:
```
      1.0e-15 *

      0.4441    0.6106    0.9175    0.1110
      0.7216    0.2220    0.2430    0.2220
      0.9159    0.2776    0.2220    0.1110
           0         0         0         0
```

No.2 solution is valid!

No.3 solution is:
```
     -0.8761
      1.3421
      4.9758
      0.8764
     -0.0222
     -0.0267
```

Its corresponding transformation matrix is:
```
      1.0000    0.0000   -0.0000    0.3000
     -0.0000    1.0000   -0.0000    0.3000
      0.0000    0.0000    1.0000         0
           0         0         0    1.0000
```

The corresponding difference with the given matrix is:
```
      1.0e-15 *

           0    0.1110    0.0604         0
      0.2220         0    0.0142    0.0555
      0.1110    0.0278         0         0
           0         0         0         0
```

No.3 solution is valid!

No.4 solution is:
```
     -0.8761
      1.3421
      4.9758
     -2.2652
     -3.1194
      3.1149
```

Its corresponding transformation matrix is:
```
      1.0000    0.0000   -0.0000    0.3000
     -0.0000    1.0000    0.0000    0.3000
      0.0000   -0.0000    1.0000    0.0000
           0         0         0    1.0000
```

The corresponding difference with the given matrix is:
```
      1.0e-15 *

           0    0.1110    0.1741    0.0555
      0.2220         0    0.0355    0.1110
      0.2220    0.0278         0    0.0555
           0         0         0         0
```

No.4 solution is valid!

No.5 solution is:
```
      2.2655
      1.7995
      1.3073
     -0.8764
      0.0222
      3.1149
```

Its corresponding transformation matrix is:
```
      1.0000         0    0.0000    0.3000
           0    1.0000    0.0000    0.3000
     -0.0000   -0.0000    1.0000    0.0000
           0         0         0    1.0000
```

The corresponding difference with the given matrix is:
```
      1.0e-15 *

           0         0    0.0604         0
           0         0    0.0142    0.1110
```

```
     0.0555    0.0278    0.2220    0.0139
          0         0         0         0


No.5 solution is valid!
----------------------------------------------------------
No.6 solution is:
     2.2655
     1.7995
     1.3073
     2.2652
     3.1194
    -0.0267


Its corresponding transformation matrix is:
     1.0000         0    0.0000    0.3000
          0    1.0000    0.0000    0.3000
    -0.0000   -0.0000    1.0000    0.0000
          0         0         0    1.0000


The corresponding difference with the given matrix is:
     1.0e-15 *

     0.1110         0    0.0693         0
          0         0    0.2203    0.0555
     0.0555    0.1943    0.2220    0.0139
          0         0         0         0


No.6 solution is valid!
----------------------------------------------------------
No.7 solution is:
    -0.8761
     0.2527
     1.3073
     1.5619
    -0.6947
    -1.5568


Its corresponding transformation matrix is:
     1.0000         0   -0.0000    0.3000
          0    1.0000   -0.0000    0.3000
     0.0000    0.0000    1.0000   -0.0000
          0         0         0    1.0000


The corresponding difference with the given matrix is:
     1.0e-15 *

     0.4441         0    0.2927    0.1665
          0    0.2220    0.4291    0.1665
     0.2776    0.3886         0    0.1110
          0         0         0         0


No.7 solution is valid!
----------------------------------------------------------
No.8 solution is:
    -0.8761
     0.2527
     1.3073
    -1.5797
    -2.4469
     1.5848


Its corresponding transformation matrix is:
     1.0000    0.0000    0.0000    0.3000
    -0.0000    1.0000   -0.0000    0.3000
    -0.0000    0.0000    1.0000   -0.0000
          0         0         0    1.0000


The corresponding difference with the given matrix is:
     1.0e-15 *

     0.2220    0.0555    0.2221    0.0555
     0.0555    0.2220    0.2665    0.0555
     0.2220    0.2220         0    0.1110
          0         0         0         0


No.8 solution is valid!
----------------------------------------------------------
Conclusion: There are 8 possible solutions in total
  Columns 1 through 7

     2.2655    2.2655   -0.8761   -0.8761    2.2655    2.2655   -0.8761
     2.8889    2.8889    1.3421    1.3421    1.7995    1.7995    0.2527
     4.9758    4.9758    4.9758    4.9758    1.3073    1.3073    1.3073
    -1.5619    1.5797    0.8764   -2.2652   -0.8764    2.2652    1.5619
     0.6947    2.4469   -0.0222   -3.1194    0.0222    3.1194   -0.6947
     1.5848   -1.5568   -0.0267    3.1149    3.1149   -0.0267   -1.5568


  Column 8

    -0.8761
     0.2527
     1.3073
    -1.5797
    -2.4469
     1.5848


************************************************************************
************************************************************************
```

```
The given hole transformation matrix is shown below:
   1.0000        0        0    0.4000
        0        0   1.0000    0.5000
        0  -1.0000        0    0.1000
        0        0        0    1.0000


No.1 solution is:
   2.4669
   2.9337
   5.8989
  -0.0000
  -0.9787
   2.4669


Its corresponding transformation matrix is:
   1.0000    0.0000   -0.0000    0.4000
   0.0000    0.0000    1.0000    0.5000
   0.0000   -1.0000    0.0000    0.1000
        0        0        0    1.0000


The corresponding difference with the given matrix is:
   1.0e-15 *

   0.2220    0.3369    0.8882        0
   0.9437    0.5480        0    0.1110
   0.4163    0.2220    0.6106    0.0833
        0        0        0        0


No.1 solution is valid!
---------------------------------------------------------
No.2 solution is:
   2.4669
   2.9337
   5.8989
   3.1416
  -2.1629
  -0.6747


Its corresponding transformation matrix is:
   1.0000    0.0000   -0.0000    0.4000
   0.0000    0.0000    1.0000    0.5000
   0.0000   -1.0000    0.0000    0.1000
        0        0        0    1.0000


The corresponding difference with the given matrix is:
   1.0e-15 *

   0.1110    0.2240    0.2776    0.1665
   0.2220    0.3895    0.1110    0.2220
   0.2498    0.2220    0.4163    0.0833
        0        0        0        0


No.2 solution is valid!
---------------------------------------------------------
No.3 solution is:
  -0.6747
   0.5366
   5.8989
   0.0000
   1.4185
  -0.6747


Its corresponding transformation matrix is:
   1.0000   -0.0000        0    0.4000
  -0.0000   -0.0000    1.0000    0.5000
  -0.0000   -1.0000   -0.0000    0.1000
        0        0        0    1.0000


The corresponding difference with the given matrix is:
   1.0e-15 *

        0    0.3393        0        0
   0.0555    0.2972        0    0.1110
   0.3331        0    0.3331    0.1388
        0        0        0        0


No.3 solution is valid!
---------------------------------------------------------
No.4 solution is:
  -0.6747
   0.5366
   5.8989
  -3.1416
   1.7231
   2.4669


Its corresponding transformation matrix is:
   1.0000   -0.0000    0.0000    0.4000
  -0.0000   -0.0000    1.0000    0.5000
  -0.0000   -1.0000   -0.0000    0.1000
        0        0        0    1.0000


The corresponding difference with the given matrix is:
   1.0e-15 *

   0.2220    0.3446    0.3886    0.0555
```

```
    0.3886     0.2931     0.2220          0
    0.2776          0     0.3331     0.0833
         0          0          0          0
```

No.4 solution is valid!

No.5 solution is:
```
    2.4669
    2.6050
    0.3842
   -0.0000
   -1.4185
    2.4669
```

Its corresponding transformation matrix is:
```
    1.0000    -0.0000         0     0.4000
    0.0000    -0.0000    1.0000     0.5000
   -0.0000    -1.0000   -0.0000     0.1000
         0         0         0     1.0000
```

The corresponding difference with the given matrix is:
```
    1.0e-15 *

         0     0.1660          0     0.0555
    0.1110     0.0805          0     0.1110
    0.1665          0     0.0555     0.0278
         0          0          0          0
```

No.5 solution is valid!

No.6 solution is:
```
    2.4669
    2.6050
    0.3842
    3.1416
   -1.7231
   -0.6747
```

Its corresponding transformation matrix is:
```
    1.0000    -0.0000     0.0000     0.4000
   -0.0000     0.0000     1.0000     0.5000
   -0.0000    -1.0000     0.0000     0.1000
         0         0         0     1.0000
```

The corresponding difference with the given matrix is:
```
    1.0e-15 *

    0.1110     0.0671     0.1665     0.0555
    0.1110     0.0537          0          0
    0.1110          0     0.0555     0.0278
         0          0          0          0
```

No.6 solution is valid!

No.7 solution is:
```
   -0.6747
    0.2079
    0.3842
    0.0000
    0.9787
   -0.6747
```

Its corresponding transformation matrix is:
```
    1.0000    -0.0000          0     0.4000
    0.0000     0.0000     1.0000     0.5000
   -0.0000    -1.0000     0.0000     0.1000
         0         0         0     1.0000
```

The corresponding difference with the given matrix is:
```
    1.0e-16 *

         0     0.6192          0     0.5551
    0.5551     0.4954          0          0
    0.8327          0     0.8327          0
         0          0          0          0
```

No.7 solution is valid!

No.8 solution is:
```
   -0.6747
    0.2079
    0.3842
   -3.1416
    2.1629
    2.4669
```

Its corresponding transformation matrix is:
```
    1.0000    -0.0000     0.0000     0.4000
   -0.0000    -0.0000     1.0000     0.5000
   -0.0000    -1.0000   -0.0000     0.1000
         0         0         0     1.0000
```

The corresponding difference with the given matrix is:
```
    1.0e-15 *

    0.2220     0.1401     0.3886          0
    0.3886     0.0657     0.2220     0.1110
    0.1110          0     0.0833     0.0833
```

```
         0           0           0           0

No.8 solution is valid!
   --------------------------------------------------------
Conclusion: There are 8 possible solutions in total
In radians:
  Columns 1 through 7

    2.4669     2.4669    -0.6747    -0.6747     2.4669     2.4669    -0.6747
    2.9337     2.9337     0.5366     0.5366     2.6050     2.6050     0.2079
    5.8989     5.8989     5.8989     5.8989     0.3842     0.3842     0.3842
   -0.0000     3.1416     0.0000    -3.1416    -0.0000     3.1416     0.0000
   -0.9787    -2.1629     1.4185     1.7231    -1.4185    -1.7231     0.9787
    2.4669    -0.6747    -0.6747     2.4669     2.4669    -0.6747    -0.6747

  Column 8

   -0.6747
    0.2079
    0.3842
   -3.1416
    2.1629
    2.4669

In degrees:
  Columns 1 through 7

  141.3402   141.3402   -38.6598   -38.6598   141.3402   141.3402   -38.6598
  168.0885   168.0885    30.7433    30.7433   149.2567   149.2567    11.9115
  337.9846   337.9846   337.9846   337.9846    22.0154    22.0154    22.0154
   -0.0000   180.0000     0.0000  -180.0000    -0.0000   180.0000     0.0000
  -56.0732  -123.9268    81.2721    98.7279   -81.2721   -98.7279    56.0732
  141.3402   -38.6598   -38.6598   141.3402   141.3402   -38.6598   -38.6598

  Column 8

   -38.6598
    11.9115
    22.0154
  -180.0000
   123.9268
   141.3402

***************************Question (b)********************************
**************************Starts here******************************

The elbow manipulator is in the following configuration (No.7 config) when inserting the peg into the hole:
   -0.6747
    0.2079
    0.3842
    0.0000
    0.9787
   -0.6747

The desired joint angle rates for achieving the target end-effector speed of only -0.01 m/s along z-axis is:
   -0.0000
    0.0372
   -0.0556
    0.0000
    0.0184
    0.0000
```