Short Project.

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After atending the Laboratory session and Theory classes you must be able to answer the following questions. Add the necessary matlab and RTB sentences to this script for reporting your result. I strongly recoment to use as a reference help for the RTB the file 'robot.pdf' http://petercorke.com/wordpress/toolboxes/robotics-toolbox

Sketching the enviroment of the robotics work cell.

It is spected: main reference frames. Plot the robot Puma, draw the working table and the torus in working position. Give diferent points of view of the scenary: Top, Front, Lateral and isometrics view

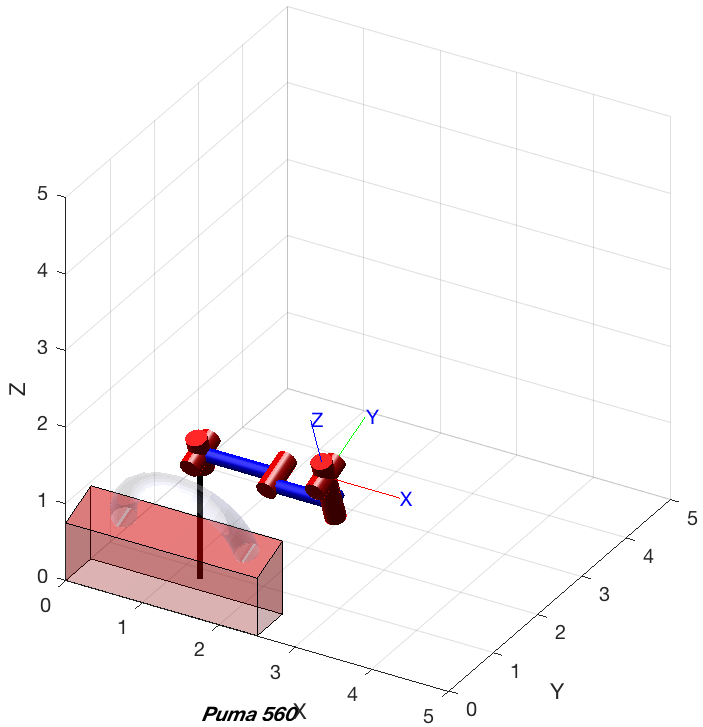
```
F1 = [0 2.5 2.5 0; 0 0 0.75 0.75; 0 0 0 0; 1 1 1 1];
F1 = trotx(90)*F1;

F2 = [0 2.5 2.5 0; 0 0 0.6 0.6; 0 0 0 0; 1 1 1 1];
F2 = transl(0,0,0.75) * trotx(20) * F2;

F3 = [0 0.75 0.75 -sin(pi/9)*0.6; 0 0 cos(pi/9)*0.6 cos(pi/9)*0.6; 0 0
 0 0; 1 1 1 1];
F3 = transl(0,0,0.75) * troty(90)*F3;

F4 = transl(2.5,0,0) * F3;

F5 = [0 2.5 2.5 0; 0 0 sin(pi/9)*0.6+0.75 sin(pi/9)*0.6+0.75; 0 0 0 0;
 1 1 1 1];
F5 = transl(0,0.6*cos(pi/9),0) * trotx(90) * F5;

figure
xlabel('x');
ylabel('y');
zlabel('z');
axis 'equal';
fill3(F1(1,:),F1(2,:),F1(3,:),'r',F2(1,:),F2(2,:),F2(3,:),'r',
 F3(1,:),F3(2,:),F3(3,:),'r', F4(1,:),F4(2,:),F4(3,:),'r',
 F5(1,:),F5(2,:),F5(3,:),'r');
alpha 0.3

fv=stlread('Torus.stl');% fv is a struct with faces and vertices
fv.vertices=fv.vertices;
ma=max(fv.vertices); mi=min(fv.vertices); dmami=ma-mi;
scale = 0.3/dmami(2);

fv.vertices = scale .* fv.vertices
```

```
[n,~] = size(fv.vertices);
fv.vertices = [transpose(fv.vertices); ones(1,n)];

% fv.vertices = scale .* fv.vertices (Scale torus solution)
fv.vertices = transl(0.6,0.3*cos(pi/9),(0.75+sin(pi/9)*0.3)) *
 trotx(-160) * fv.vertices;

[m,~] = size(fv.vertices);
fv.vertices(m,:)=[];
fv.vertices = transpose(fv.vertices);

SS=patch(fv,'FaceColor',       [0.8 0.8 1.0], ...
         'EdgeColor',       'none',        ...
         'FaceLighting',    'gouraud',     ...
         'AmbientStrength', 0.15);
% Add a camera light, and tone down the specular highlighting
camlight('headlight');
material('dull');
alpha (SS,0.2)
view(30,30)
% Fix the axes scaling, and set a nice view angle
axis('image');
axis 'equal'

mdl_puma560
p560.base = transl(1.3, cos(pi/9)*0.3+0.5, 1.65)*trotx(20);
p560.links(1, 2).a=1
p560.links(1, 3).a=0.8
p560.plot(qz);
hold on;
axis([0 5 0 5 0 5]);
```

```
fv =

  struct with fields:

      faces: [668×3 double]
   vertices: [2004×3 double]
```

```
p560 =

Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, fastRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|          1|          0|          0|
|  3|         q3|    0.15005|     0.0203|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
```

```
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
base:    t = (1.3, 0.782, 1.65), RPY/xyz = (0, 0, 20) deg


p560 =

Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, fastRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|          1|          0|          0|
|  3|         q3|    0.15005|        0.8|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
base:    t = (1.3, 0.782, 1.65), RPY/xyz = (0, 0, 20) deg

Warning: floor tiles too small, making them 2.000000 x bigger - change
 the size
or disable them
Warning: arrow option requires arrow3 from FileExchange
```



Working points.

Give here your code to get the variables to locate: a) The reference frame for all drills holes, such that z-axis is orthogonal to the surface of the torus and the x-axis is in the direction of minimun curvature. Draw in scale the frames b) Repeat the obove operation for the center of the milling groove. Draw this frames. c) The reference frames for all welding points, such that z-axis of the tool is orthogonal to the surface of the torus and the x-axis is in the direction of spiral trajectory. Draw in scale the frames

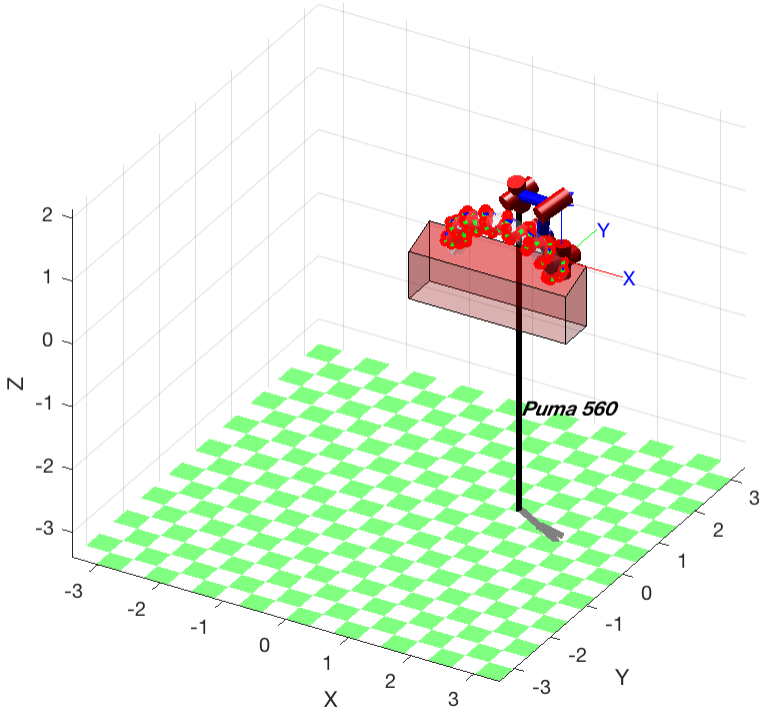
```
    n=8; m=8; px=-0.8;py=0;pz=0;r=0.15;
    for i=0:m
        for j=1:n
            if (i~=8)
                Ptos_spiral(:,:,i*n+j)=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(180*(i*n+j)/
(n*m))*transl(px,py,pz)*trotz(360*j/n)*transl(r,0,0);

                Ptos_spiral_welding(:,:,i*n*3+(3*j)-2)=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(180*(i*n+j)/
(n*m))*transl(px,py,pz)*trotz(360*j/n)*transl(r*3,0,0);
                Ptos_spiral_welding(:,:,i*n*3+(3*j)-1)=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(180*(i*n+j)/
(n*m))*transl(px,py,pz)*trotz(360*j/n)*transl(r,0,0);
                Ptos_spiral_welding(:,:,i*n*3+(3*j))=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(180*(i*n+j)/
(n*m))*transl(px,py,pz)*trotz(360*j/n)*transl(r*3,0,0);
            end
        end
    end

    coor_circle=transl(Ptos_spiral)';

 plot3(coor_circle(1,:),coor_circle(2,:),coor_circle(3,:),'g','LineWidth',2);

 scatter3(coor_circle(1,:),coor_circle(2,:),coor_circle(3,:),'r','fillet');
    axis equal

     for i=0:m-1
        for j=1:4
            if (j==1)
                Q = p560.ikine6s(transl(Ptos_spiral_welding(:,:,(i*3*m
+1):(3*i*m+1)+3*2*j)), 'run');
            elseif (j==2)
                Q = p560.ikine6s(transl(Ptos_spiral_welding(:,:,(i*3*m
+1)+6:(3*i*m+1)+3*2*j-3)), 'run');
            elseif (j==3)
              Q = p560.ikine6s(transl(Ptos_spiral_welding(:,:,(i*3*m
+1)+12-3:(3*i*m+1)+3*2*j+3)), 'lun');
            else
                Q = p560.ikine6s(transl(Ptos_spiral_welding(:,:,(i*3*m
+1)+18+3:(3*i*m+1)+3*2*j-1)), 'ldn');
            end
            p560.plot(Q);
        end
```

```
    end
    (3*(m-1)*m+1)+3*2*4
    s=8; c=20; r=0.01; l=0.08; offset=15;
    for i=0:s
       if(i~=s)
            for j=1:c
                if(j==c)
                    Ptos_groove(:,:,i*c+j)=Ptos_groove(:,:,i*c+1);
                elseif (j<c/2)
                    Ptos_groove(:,:,i*c+j)=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.95,0,sin(degtorad(-90+180*i/s))*0.95)*troty(180*i/
s)*trotz(90)*trotz(360*j/c)*transl(r,0,0);
                else
                    Ptos_groove(:,:,i*c+j)= transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.95,0,sin(degtorad(-90+180*i/s))*0.95)*troty(180*i/
s)*trotz(90)*transl(0,-l,0)*trotz(360*j/c)*transl(r,0,0);
                end
            end
        Ptos_groove_mill(:,:,(4*i)+1) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*1.2,0,sin(degtorad(-90+180*i/s))*1.2)*troty(180*i/s)*trotz(90);
        Ptos_groove_mill(:,:,(4*i)+2) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.95,0,sin(degtorad(-90+180*i/s))*0.95)*troty(180*i/s)*trotz(90);
        Ptos_groove_mill(:,:,(4*i)+3) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.95,0,sin(degtorad(-90+180*i/s))*0.95)*troty(180*i/
s)*trotz(90)*transl(0,-l,0);
        Ptos_groove_mill(:,:,(4*i)+4) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*1.2,0,sin(degtorad(-90+180*i/s))*1.2)*troty(180*i/
s)*trotz(90)*transl(0,-l,0);
       end
    end

    coor_groove = transl(Ptos_groove)';
    coor_groove_mill = transl(Ptos_groove_mill)';

    for i=0:7
       plot3(coor_groove(1,i*c+1:(i+1)*c),coor_groove(2,i*c+1:(i
+1)*c),coor_groove(3,i*c+1:(i+1)*c),'b','LineWidth',1);
    end

    for i=0:7
        if (i < 4)
            Q = p560.ikine6s(transl(Ptos_groove_mill(:,:,(i*4+1):(i
+1)*4)), 'run');
        else
            Q = p560.ikine6s(transl(Ptos_groove_mill(:,:,(i*4+1):(i
+1)*4)), 'luf');
        end
        p560.plot(Q);
```

```
    end


    s=8; c=40; r=0.02; offset=13.5;
    for i=0:s
       if(i~=s)
            for j=1:c
                 Ptos_circle(:,:,i*c+j)=transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.8,0.15,sin(degtorad(-90+180*i/s))*0.8)*trotx(90)*trotz(360*j/
c)*transl(r,0,0);
            end
        Ptos_circle_drill(:,:,(3*i)+1) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.8,0.2,sin(degtorad(-90+180*i/s))*0.8)*trotx(90);
        Ptos_circle_drill(:,:,(3*i)+2) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.8,0.15,sin(degtorad(-90+180*i/s))*0.8)*trotx(90);
        Ptos_circle_drill(:,:,(3*i)+3) = transl(0.6-
px,0.3*cos(pi/9),0.75+sin(pi/9)*0.3)*trotx(20)*troty(90+offset)*transl(cos(degtora
s))*0.8,0.2,sin(degtorad(-90+180*i/s))*0.8)*trotx(90);
       end
    end

    coor_circle = transl(Ptos_circle)';
    % coor_circle_drill = transl(Ptos_circle_drill)';

    for i=0:7
       plot3(coor_circle(1,i*c+1:(i+1)*c),coor_circle(2,i*c+1:(i
+1)*c),coor_circle(3,i*c+1:(i+1)*c),'b');

    end

    for i=0:7
        if (i < 4)
            Q = p560.ikine6s(transl(Ptos_circle_drill(:,:,(i*3+1):(i
+1)*3)), 'run')
        else
            Q = p560.ikine6s(transl(Ptos_circle_drill(:,:,(i*3+1):(i
+1)*3)), 'run')
        end
        p560.plot(Q);
    end



  %scatter3(coor_circle_drill(1,:),coor_circle_drill(2,:),coor_circle_drill(3,:),'

    axis equal


ans =

   193
```

```
Q =

   -2.2929    0.5440    3.6730    0.3104    2.3084    2.4747
   -2.2558    0.5433    3.7091    0.2903    2.2843    2.4186
   -2.2929    0.5440    3.6730    0.3104    2.3084    2.4747


Q =

   -2.1645    0.9105    3.4644    0.2368    2.1879    2.2748
   -2.1293    0.9019    3.5063    0.2202    2.1629    2.2260
   -2.1645    0.9105    3.4644    0.2368    2.1879    2.2748


Q =

   -1.8600    1.2726    3.3010    0.1097    2.0428    1.8935
   -1.8383    1.2469    3.3507    0.1006    2.0212    1.8668
   -1.8600    1.2726    3.3010    0.1097    2.0428    1.8935


Q =

   -1.3372    1.5055    3.2384   -0.0832    1.8786    1.3256
   -1.3574    1.4603    3.2922   -0.0759    1.8716    1.3474
   -1.3372    1.5055    3.2384   -0.0832    1.8786    1.3256


Q =

   -0.8376    1.4253    3.3101   -0.2376    1.8054    0.8122
   -0.8901    1.3891    3.3593   -0.2231    1.8047    0.8678
   -0.8376    1.4253    3.3101   -0.2376    1.8054    0.8122


Q =

   -0.5687    1.1365    3.4784   -0.3044    1.8492    0.5112
   -0.6211    1.1175    3.5199   -0.2929    1.8430    0.5699
   -0.5687    1.1365    3.4784   -0.3044    1.8492    0.5112


Q =

   -0.4482    0.7981    3.6887   -0.3360    1.9333    0.3498
   -0.4949    0.7886    3.7245   -0.3265    1.9233    0.4049
   -0.4482    0.7981    3.6887   -0.3360    1.9333    0.3498


Q =

   -0.4030    0.4619    3.9062   -0.3587    2.0302    0.2611
```

```
-0.4465    0.4573    3.9388   -0.3492    2.0183    0.3150
-0.4030    0.4619    3.9062   -0.3587    2.0302    0.2611
```



Computing motor torques for the static forces.co

Give here your code to fill two tables with the motor torque at each robot pose: Table 1 (6x16): Rows are the motor torques (6x1). Columns (1x16) are the labeled drills including the initial drill before milling. Table 2 (6x8): Rows are the motor torques (6x1). Columns (1x8) are the labeled milling of the groove.

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