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.

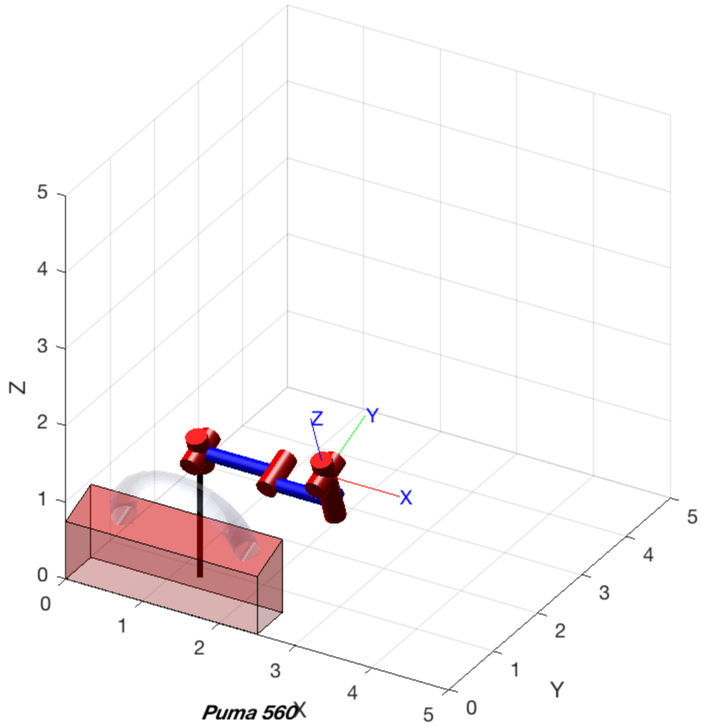
It is spected: main reference frames. Plot the robot Puma, draw the working table and the torus in working position. Give diferent points of view of the scenary: Top, Front, Lateral and isometrics view

```
% Initialization of the faces of the table (placing suposing floor is
 on
% z=0 and positioned with its frontal left vertex at (0,0,0)
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;

% Plotting the table
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

% Loading the Torus and scaling it to fit the size of the instructions
fv=stlread('Torus.stl');
```

```
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

% Preparing the torus to interact with it by appending a column of 1s
 to
% the transposed fv.vertices
[n,~] = size(fv.vertices);
fv.vertices = [transpose(fv.vertices); ones(1,n)];

% Placing the torus onto de table
fv.vertices = transl(0.6,0.3*cos(pi/9),(0.75+sin(pi/9)*0.3)) *
 trotx(-160) * fv.vertices;

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

% Preparing to plot Torus
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'

% Loading the puma and setting it up + ploting it.
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 above 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

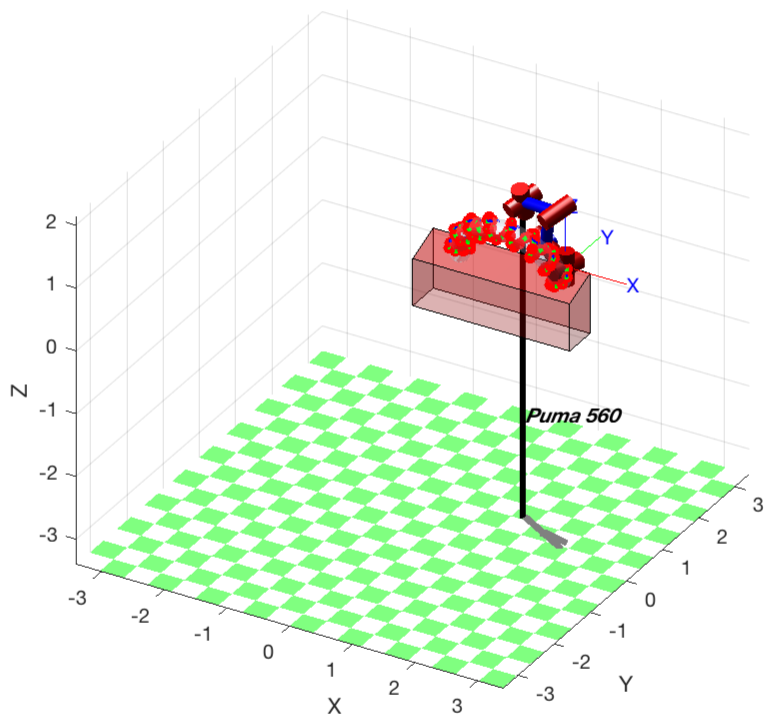
```
    % Calculation of the welding points. We use 2 variables.

        % 1. Ptos_spiral: it defines the points where we have to weld
 in order
        % to plot them

        % 2.Ptos_spiral_welding: it defines de poses puma has to do in
        % order to reach each point. (3 points x welding point)

    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

    % Plot of the welding points + line throught them
    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

    % Animation for the puma, using the previously calculated
    % Ptos_spiral_welding.

    % Each circle of the spiral is divided into 4 different parts in
 order
    % to change the access pose of the robot depending on the position
    % of the torus it is accessing

     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

      % Calculation of the milling points. We use 2 variables.

        % 1. Ptos_groove: it defines the places where it is necessary
 to
        % groove and it stores the points which define each groove.
```

```
        % 2.Ptos_groove_mill: it defines de poses puma has to do in
        % order to reach each point and to mill (4 points x milling
 point)

    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

    % Ploting the grooves
    coor_groove = transl(Ptos_groove)';

    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

    % Animation of the puma, using the previously calculated
    % Ptos_groove_milling.

    % We use the previously calculated points in the  Ptos_groove_mill
 and
    % divide them in two groups. The left and the right ones to make
 the
```

```
    % pose vary due to that variable

    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

    % Calculation of the drilling points. We use 2 variables.

        % 1. Ptos_circle: it defines the places where it is necessary
 to
        % drill and it stores the points which define each circle.

        % 2.Ptos_circle_drill: it defines de poses puma has to do in
        % order to reach each point and to drill (3 points x drilling
 point)

    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

    % Ploting the circles
    coor_circle = transl(Ptos_circle)';

    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
```

```
% Animation of the puma, using the previously calculated
% Ptos_circle_drill.

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

axis equal
```



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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