

Template of Manipulator Short project: Skull tumor surgery

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Shared Link with the teacher: <https://drive.mathworks.com/sharing/09b55873-900d-4ef4-a139-6397e28575bd>

Remember use the options of serial/link plot:

'workspace' for centering in the surgery task

'zoom' ... nice puma ratio aspect

'trail' .. to see the trajectory

etc..

See all at:

>> help SerialLink/plot

Table of Contents

The Robotic environment (10%).....	1
Operating table.....	1
3D model of a human body	3
Dicom image vs Image Reference frame {I}.....	5
Fiducials wrt {I}.....	7
Tumor points wrt {I}.....	9
Fiducials and Tumor wrt Human Reference Frame.....	11
Reference Frames.....	13

The Robotic environment (10%)

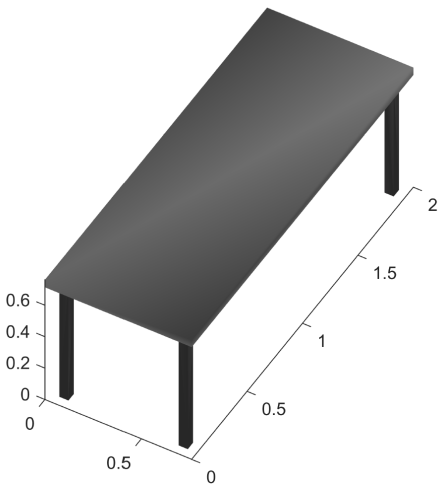
Think that later on the enviroment will move to any place in a Univers Reference Frame {U}

Use: 'c = uisetcolor' to chose your prefered colors

Operating table.

It can be raised, lowered, and tilted in any direction, and an auxiliary table for the tools. Define: Vertices and Faces and use 'patch' functions to model it. See help patch to find and example.

Expected results



```

clear
close all
clf

T_M_U = transl(10,8,0.8)*trotz(pi/6); % Reference Frame Taula

v_ini= [0 0 0;1 0 0;1 1 0;0 1 0;0 0 1;1 0 1;1 1 1;0 1 1];
LDH = [2 0 0; 0 1 0; 0 0 0.1];
v = v_ini * LDH;
v = [v ones(size(v,1),1)];
v = (T_M_U * v)';
f = [1 2 6 5;2 3 7 6;3 4 8 7;4 1 5 8;1 2 3 4;5 6 7 8];

mesa = figure;
figure(mesa);
patch('Vertices',v(:,(1:3)),'Faces',f,'FaceVertexCData',hsv(6),'FaceColor',[0.5,
0.5 0.5], 'EdgeColor', 'none', 'FaceLighting', 'gouraud', 'AmbientStrength',0.15)
view(30,45)
axis equal

v_pata = v_ini * [0.1 0 0; 0 0.1 0; 0 0 0.7];
v_pata = [v_pata ones(size(v_pata,1),1)];

v_pata1 = (T_M_U * transl(0,0,-0.7) * v_pata)';
v_pata2 = (T_M_U * transl(1.9,0,-0.7) * v_pata)';
v_pata3 = (T_M_U * transl(1.9,0.9,-0.7) * v_pata)';
v_pata4 = (T_M_U * transl(0,0.9,-0.7) * v_pata)';

patch('Vertices',v_pata1(:,(1:3)),'Faces',f,'FaceVertexCData',hsv(6),'FaceColor',
[0.5, 0.5 0.5], 'EdgeColor', 'none', 'FaceLighting', 'gouraud',
'AmbientStrength',0.15)
patch('Vertices',v_pata2(:,(1:3)),'Faces',f,'FaceVertexCData',hsv(6),'FaceColor',
[0.5, 0.5 0.5], 'EdgeColor', 'none', 'FaceLighting', 'gouraud',
'AmbientStrength',0.15)

```

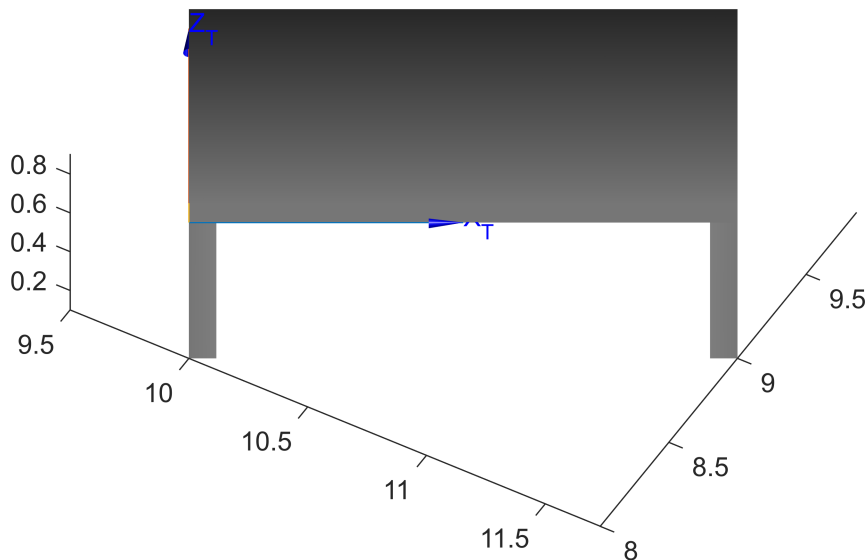
```

patch('Vertices',v_pata3(:,(1:3)),'Faces',f,'FaceVertexCData',hsv(6),'FaceColor',
[0.5, 0.5 0.5], 'EdgeColor', 'none', 'FaceLighting', 'gouraud',
'AmbientStrength',0.15)
patch('Vertices',v_pata4(:,(1:3)),'Faces',f,'FaceVertexCData',hsv(6),'FaceColor',
[0.5, 0.5 0.5], 'EdgeColor', 'none', 'FaceLighting', 'gouraud',
'AmbientStrength',0.15)

camlight('headlight')
material('dull')
view(30,45)
axis equal
hold on

trplot(T_M_U, 'frame', 'T', 'length', 1, 'arrow', 'color', 'b');

```

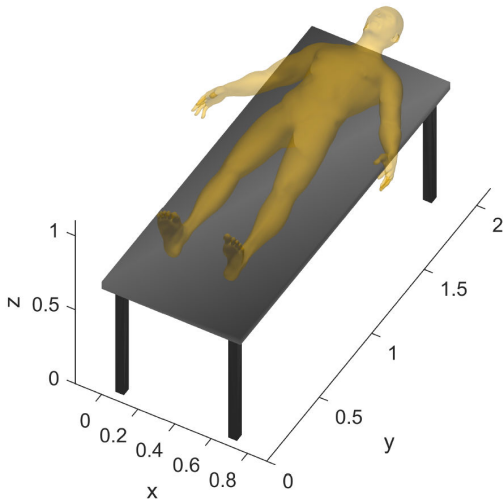


3D model of a human body

Situate the human model on the operating table.

Use: F_V_HumanBody.mat as a model

Expected results

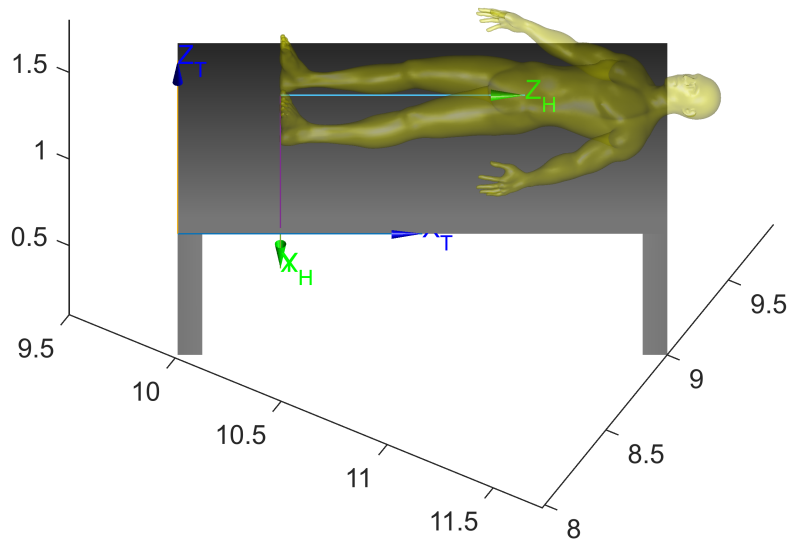


```
load("F_V_HumanBody.mat")

T_H_M = T_M_U * transl(0.42,0.5,0.3) * troty(pi/2) * trotx(-pi/2); % Reference
Frame Humà wrt Taula
v_human = [Vh ones(size(Vh, 1),1)];
v_human = (T_H_M * v_human)';

patch('Vertices',v_human(:,
(1:3)), 'Faces',Fh, 'FaceVertexCData',hsv(6), 'FaceColor','y', 'FaceAlpha',
0.3, 'EdgeColor', 'none', 'FaceLighting', 'gouraud', 'AmbientStrength',0.15)
axis equal

trplot(T_H_M, 'frame', 'H', 'length', 1, 'arrow', 'color', 'g');
```

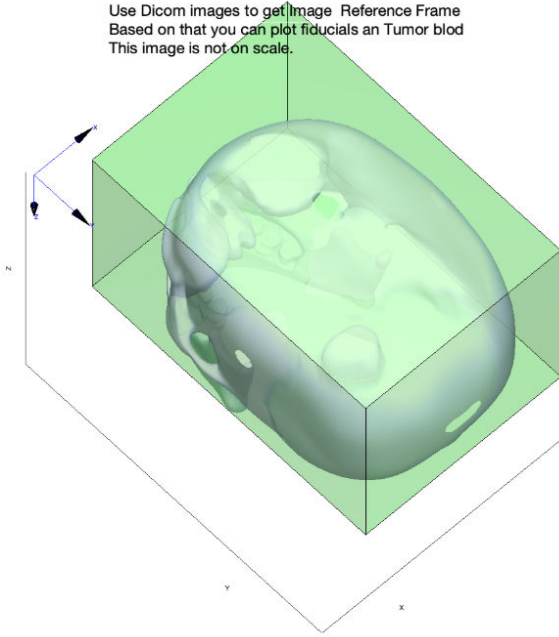


Dicom image vs Image Reference frame $\{I\}$

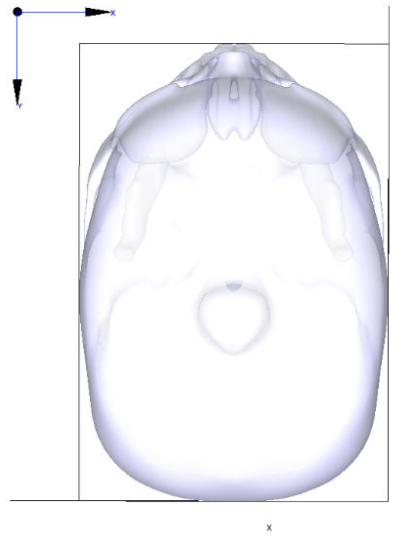
Get familiar with Dicom Images and the functionalities of the viewer, Visit: <https://www.dicomlibrary.com>

Infer the Image Reference Frame $\{I\}$ and the skull containing box dimensions.

Use Dicom images to get Image Reference Frame
Based on that you can plot fiducials an Tumor blod
This image is not on scale.



Use Dicom images to get Image Reference Frame
Based on that you can plot fiducials an Tumor blod
This image is not on scale.



```
skull = load("F_V_Skull.mat");
skull_vertices = skull.Vs;

T_I = troty(pi); % Reference Frame Imatge

T_CB_I = T_I * transl(0.041,0.026,0); % Reference Frame Capsa Contenidora wrt Imatge

xmaxs = max (skull_vertices(:, 1));
xmins = min(skull_vertices(:, 1));
ymaxs = max (skull_vertices(:, 2));
ymins = min(skull_vertices(:, 2));

xsize = abs(xmaxs - xmins)/2;
ysize = abs(ymaxs - ymins)/2;
zsize = max(skull_vertices(:,3));

T_Skull = T_I * transl(xsize+0.041, ysize+0.026, zsize) * troty(pi); % Ini Skull

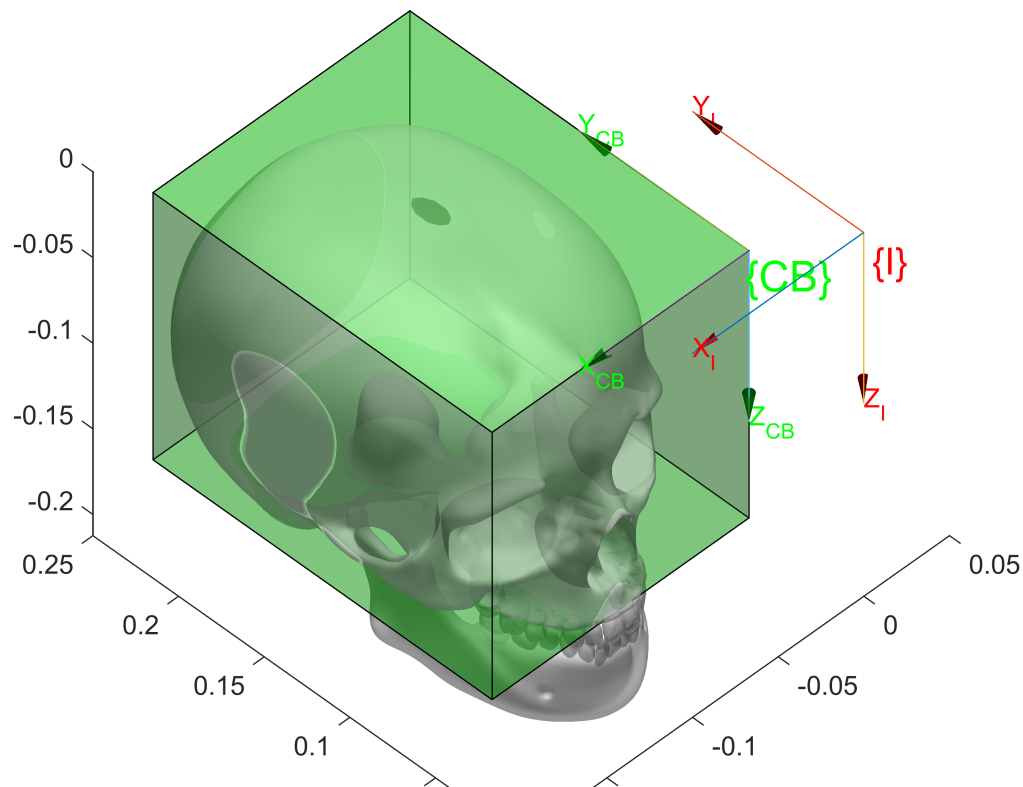
skull_vertices = [skull_vertices ones(size(skull_vertices, 1),1)];
skull_vertices = (T_Skull * skull_vertices)';

skull_fig = figure;
figure(skull_fig)

patch('Vertices',skull_vertices(:,
1:3),'Faces',skull.Fs,'FaceVertexCData',hsv(6),'FaceColor','w', 'EdgeColor',
'none', 'FaceAlpha', 0.6, 'FaceLighting', 'gouraud', 'AmbientStrength',0.15)
camlight('headlight')
material('dull')
```

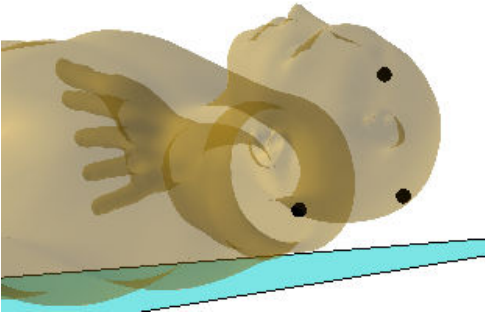
%Capsa Contenidora Skull

```
x=0.150;  
y=0.198;  
z=0.156;  
v= [0 0 0;x 0 0;x y 0;0 y 0;0 0 z;x 0 z;x y z;0 y z];  
  
cube_vertices_cb = [v'; ones(1, length(v))];  
  
cube_vertices_cb = (T_CB_I * cube_vertices_cb)';  
  
cube_faces = [ 1 2 6 5; 2 3 7 6; 3 4 8 7; 4 1 5 8; 1 2 3 4; 5 6 7 8];  
  
hold on  
  
patch('Vertices',cube_vertices_cb(:,1:3),'Faces',cube_faces,'FaceVertexCData',hsv(6),  
, 'FaceColor','g','FaceAlpha',0.3)  
trplot(T_I,'frame','I','length',0.1,'arrow','color','r')  
axis equal  
trplot(T_CB_I,'frame','CB','length',0.1,'arrow','color','g')  
axis equal  
view(-45,45)
```



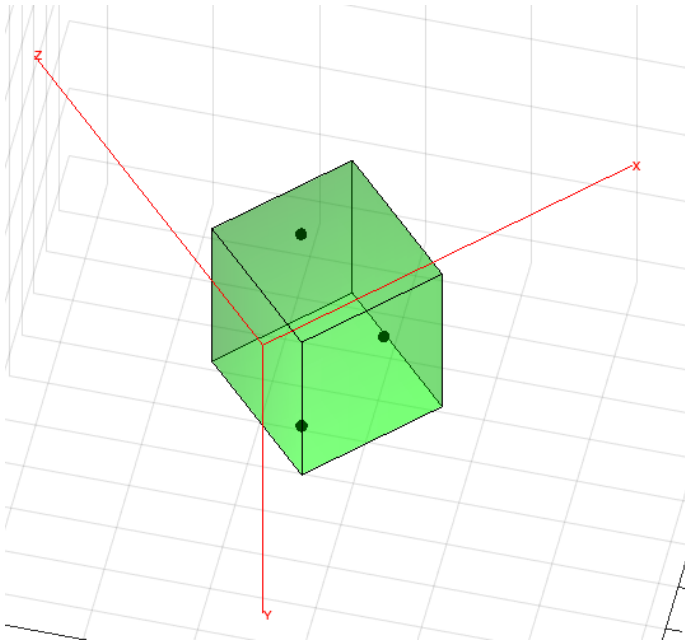
Fiducials wrt {I}

The Radiology Department before to take a Computer Tomography (CT) of the brain, fix three fiducials in the head of the patient for registering purpose, visit: <https://en.wikipedia.org/wiki/Fiducial>



Use the Dicom images to obtain the fiducial coordinates relative to Image Reference Frame {I}.

Expected results



```
F1_I = [0.06656 0.200 0.112 1]';  
F2_I = [0.186 0.209 0.0658 1]';  
F3_I = [0.122 0.062 0.0252 1]';
```

```
[X,Y,Z] = sphere;
```

```
r2 = 0.005;
```

```
X3 = X * r2;
```

```
Y3 = Y * r2;
```

```
Z3 = Z * r2;
```



```
F1_U = T_I * F1_I;
```

```
hold on
```

```
surf(X3+F1_U(1,1),Y3+F1_U(2,1),Z3+F1_U(3,1),'FaceColor',[1 0 0])
```

```
axis equal
```

```
F2_U = T_I * F2_I;
```

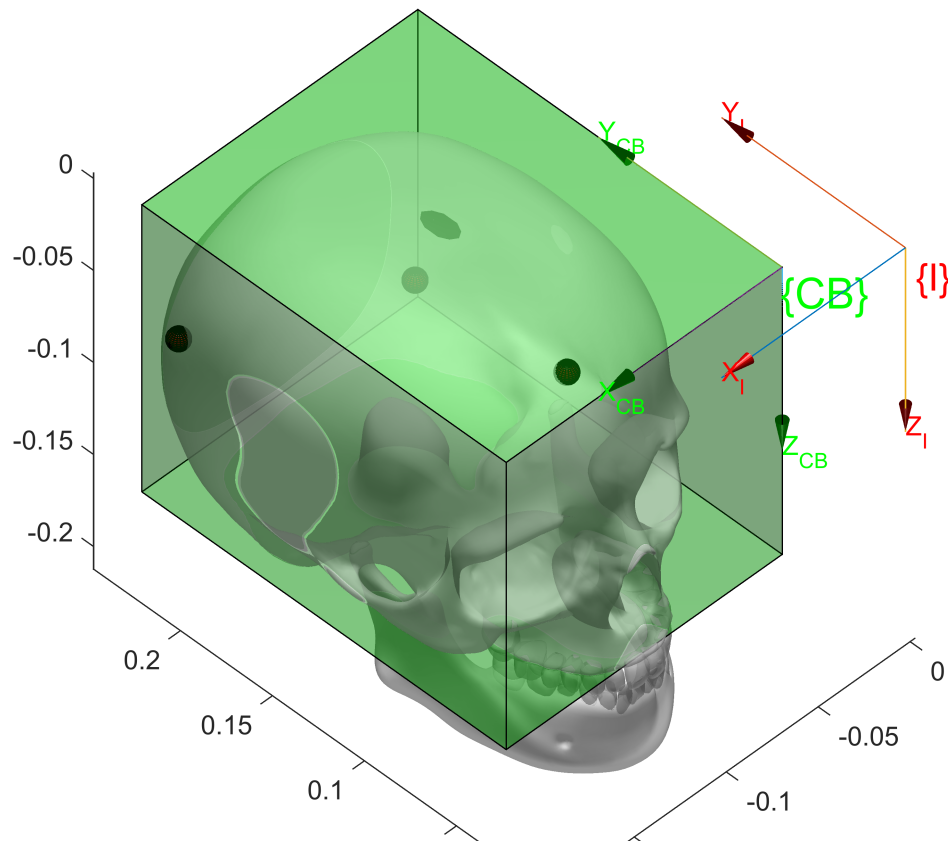
```
surf(X3+F2_U(1,1),Y3+F2_U(2,1),Z3+F2_U(3,1),'FaceColor',[1 0 0])
```

```
axis equal
```

```
F3_U = T_I * F3_I;
```

```
surf(X3+F3_U(1,1),Y3+F3_U(2,1),Z3+F3_U(3,1),'FaceColor',[1 0 0])
```

```
axis equal
```

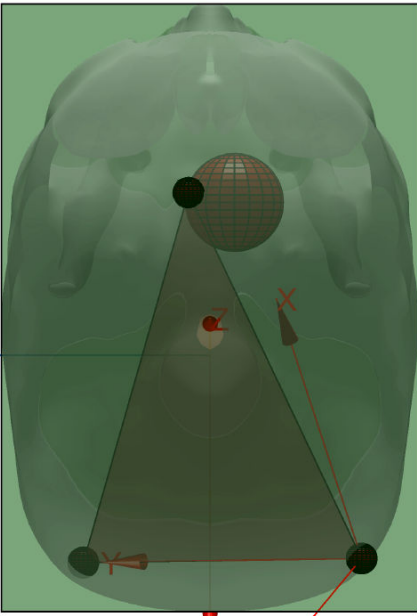


Tumor points wrt {I}

Use the Dicom images to get the points of the outer perimeter of the tumor relative to Image Reference Frame {I}.

You can simplify the tumor information by defining the center of mass and estimate an equivalent diameter.

Expected results



```
C_T = [0.130 0.097 0.049 1]'; % X Y Z (1)
D_T = 0.033;

[X,Y,Z] = sphere;

r = D_T / 2;

X2 = X * r;
Y2 = Y * r;
Z2 = Z * r;

C_T_U = T_I * C_T;

surf(X2+C_T_U(1,1), Y2+C_T_U(2,1), Z2+C_T_U(3,1), 'FaceColor', [1 0 0])
axis equal

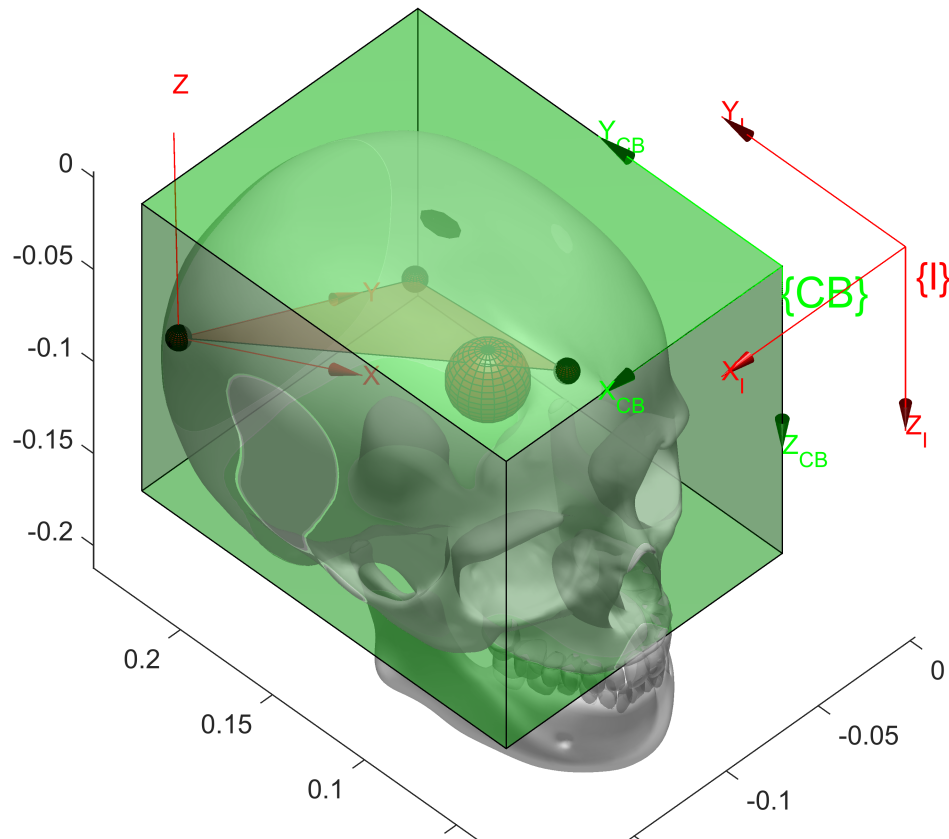
triangle = [F1_U(1:3,:), F2_U(1:3,:), F3_U(1:3,:)];
fill3(triangle(1,:), triangle(2,:), triangle(3,:)', 'r', 'FaceAlpha', 0.5)

AB = (triangle(1:3,1) - triangle(1:3,2)) / norm(triangle(1:3,1) - triangle(1:3,2));
% Vector pointing A
CB = (triangle(1:3,3) - triangle(1:3,2)) / norm(triangle(1:3,2) - triangle(1:3,3));
% Vector pointing C
Z_B = cross(CB, AB) / norm(cross(CB, AB));

orientAB = oa2r(AB, Z_B);
T_F = [orientAB F2_U(1:3); 0 0 0 1];

trplot(T_F, 'length', 0.1, 'arrow', 'color', 'r');
```

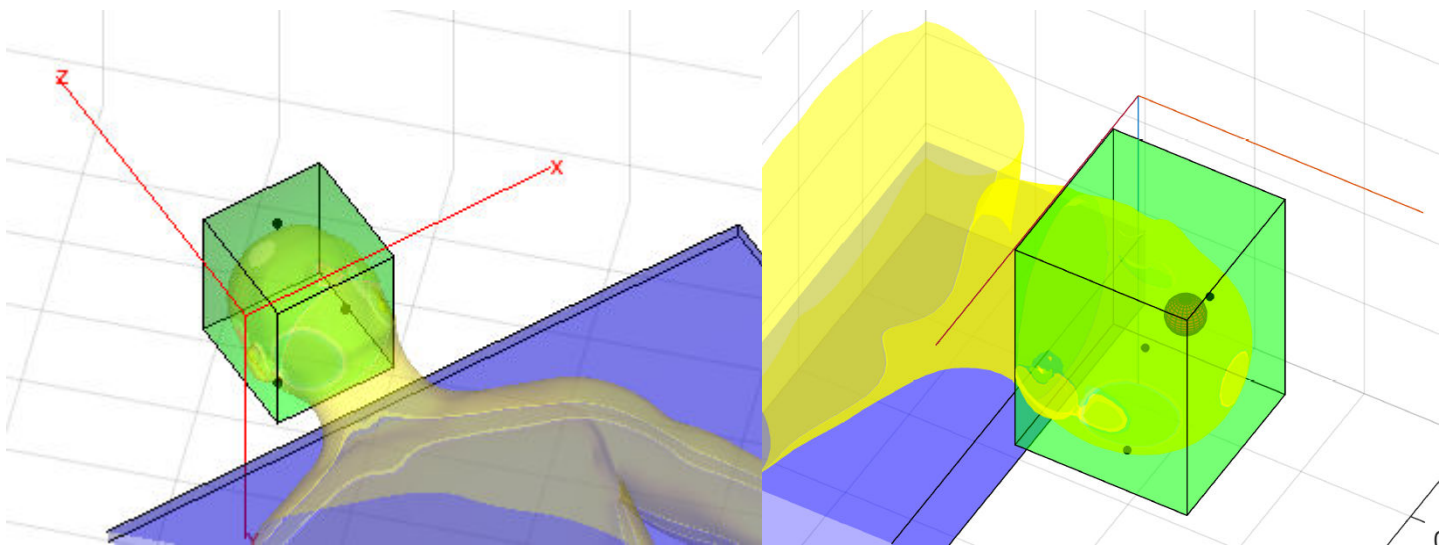
```
hold off
```



Fiducials and Tumor wrt Human Reference Frame

Place fiducial and tumor in the head of the human.

Expected results



```
figure(mesa)  
hold on
```

```

T_I_H = T_H_M * transl(-(xsize+0.041),-(ysize+0.026),1.65); % Reference Frame
Imagen wrt Humà
T_F_I = T_I_H * troty(pi) * transl(-0.235,0,-0.14);
T_CB_I = T_I_H * troty(pi);

cube_vertices_cb = (T_CB_I * cube_vertices_cb)';
patch('Vertices',cube_vertices_cb(:,
1:3),'Faces',cube_faces,'FaceVertexCData',hsv(6),'FaceColor','g','FaceAlpha',0.3)

F1_U = T_F_I * F1_I;

surf(X3+F1_U(1,1),Y3+F1_U(2,1),Z3+F1_U(3,1),'FaceColor',[1 0 0])
axis equal

F2_U = T_F_I * F2_I;
surf(X3+F2_U(1,1),Y3+F2_U(2,1),Z3+F2_U(3,1),'FaceColor',[1 0 0])
axis equal

F3_U = T_F_I * F3_I;

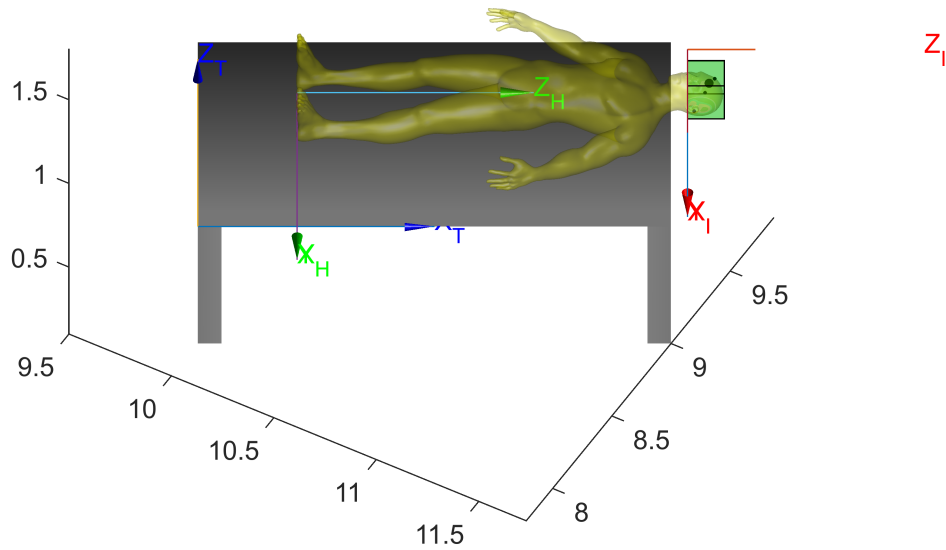
surf(X3+F3_U(1,1),Y3+F3_U(2,1),Z3+F3_U(3,1),'FaceColor',[1 0 0])
axis equal

C_T_U = T_F_I * C_T;

surf(X2+C_T_U(1,1), Y2+C_T_U(2,1), Z2+C_T_U(3,1),'FaceColor',[1 0 0])
axis equal

trplot(T_I_H,'frame', 'I', 'length', 1, 'arrow', 'color', 'r')

```



Reference Frames

Display all necessary reference frame. Use best scale to see it.

- $\{U\}$ Univers $[0 \ 0 \ 0]$
- $\{R\}$ Robot
- $\{I\}$ Image
- $\{Tb\}$ Table_body
- $\{Tt\}$ Table tool
- $\{EE\}$ End Efector
- others
- ...