A2 – Stereotactic Targeting

Transformer

The matlab file to run is ROBOTS.m, because robots are transformers in disguise. There were three main components to this assignment, the Transformer, the Simulator and the Analyzer. The transformer took in a set of [X, Y] CT fiducial coordinates and found the corresponding transformation matrix. This was accomplished by finding the plane for which the fiducial rod points 2, 5, and 8 lie on. Finding the z-depth was found by constructing a fiducial cage about the origin and taking the intersection between the z-motif and the line for which the 2D point lies on. The comments in the Transformer code contain a detailed breakdown of the algorithm for finding the HTM.

An illustration depicting the cage can be found in figure 1.

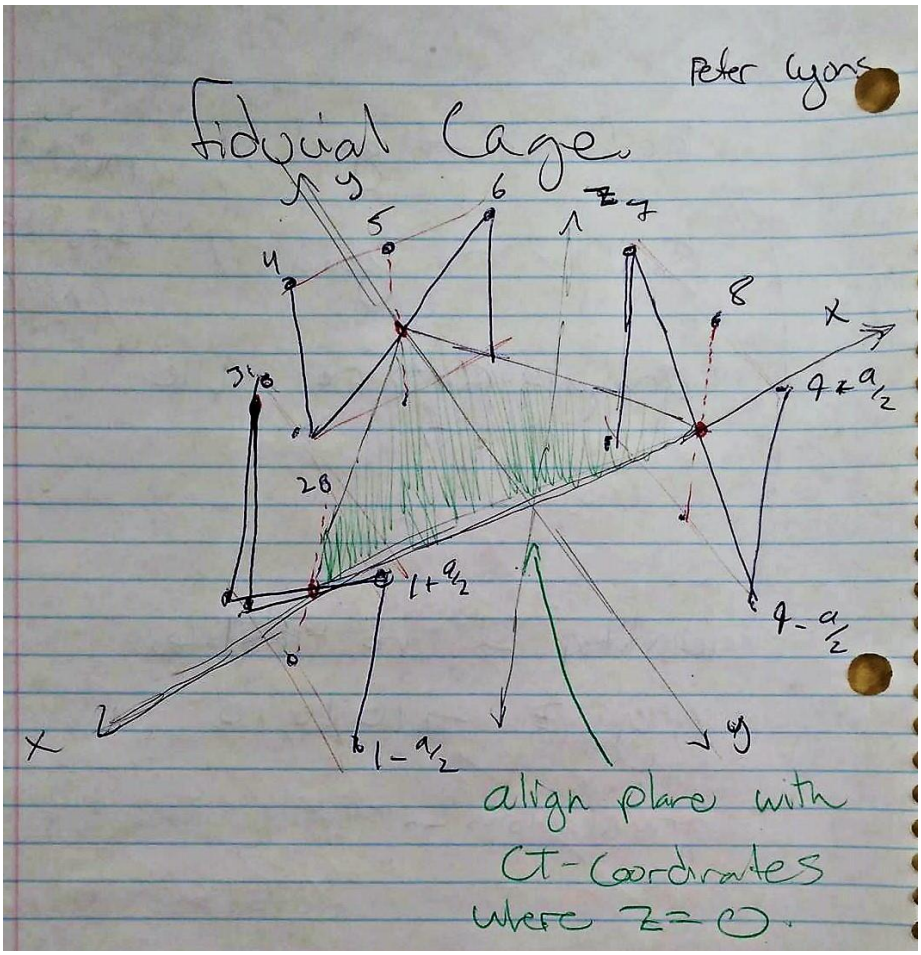

Figure 1: Depiction of the plane within a Fiducial Cage

Simulator

The Simulator takes a transformation matrix, and constructs a fiducial cage that corresponds to a homogeneous transform matrix. The general breakdown was as follows: Initialize a set of vectors around the origin. Apply the transformation matrix to the fiducial points. Next, create a fiducial cage by offsetting the points by a/2 and -a/2. Create vectors to represent the fiducial rods. Using a line-plane intersect function, the intersection along the origin plane can be found for the points along the z fiducials. The result are 2D coordinates that represent the translated image. A more detailed breakdown can be found in the code comments.

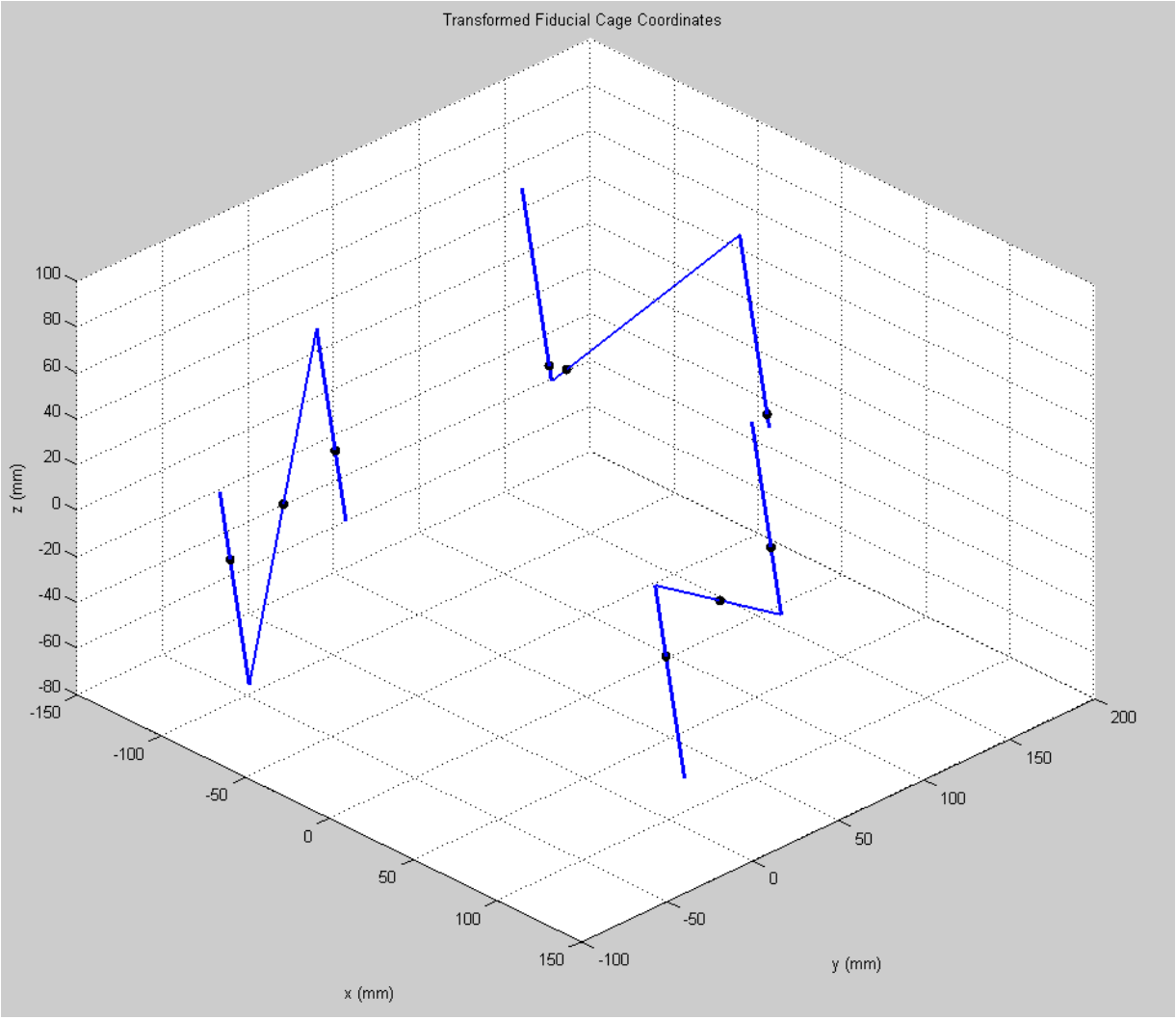

Figure 2: Reconstruction of the Fiducial Cage in from a Homogeneous Transform Matrix

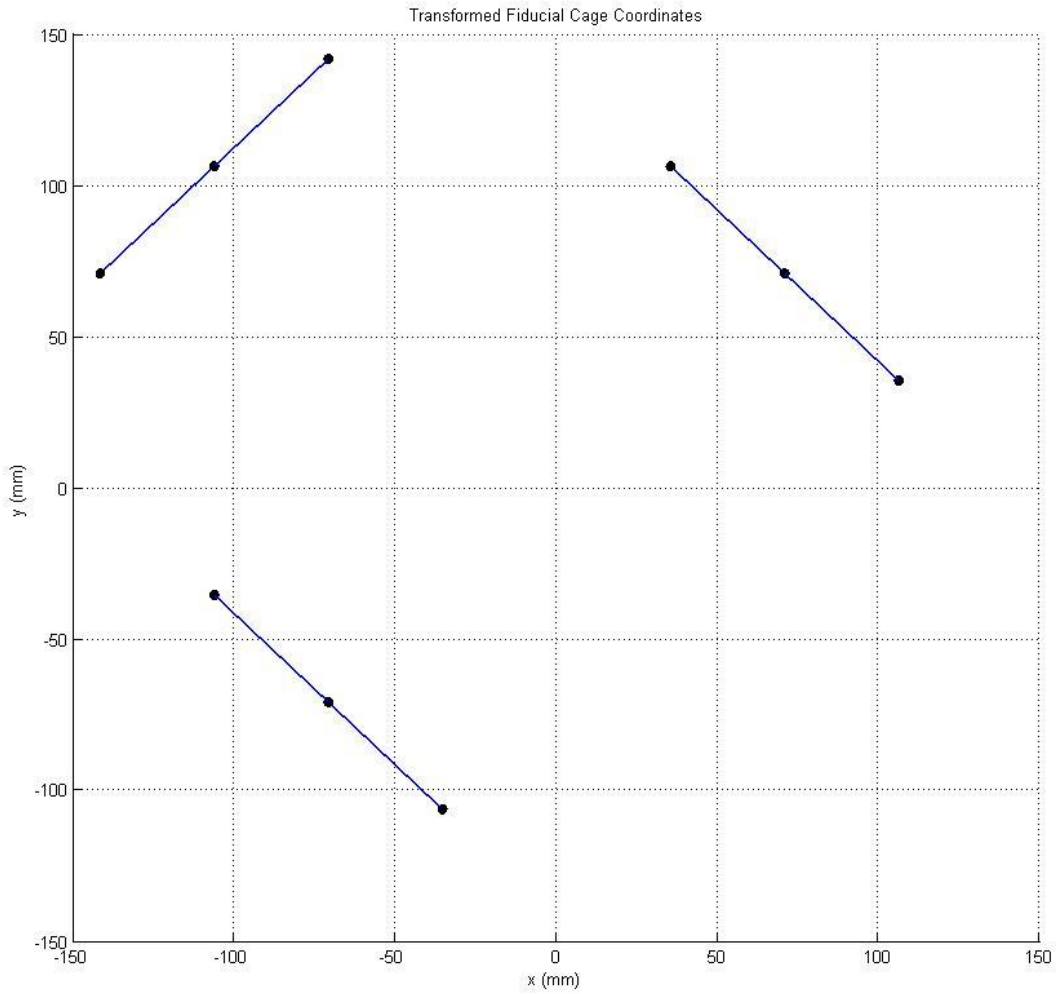

Figure 3: 45 degree rotation along z-axis

Analyzer

The analyzer repeatedly performed the Simulator and Transformer functions while introducing FLE error. The goal of this was to determine the accuracy and find the average and standard deviations of these errors. For a detailed explanation of the algorithm, please read the code file comments.

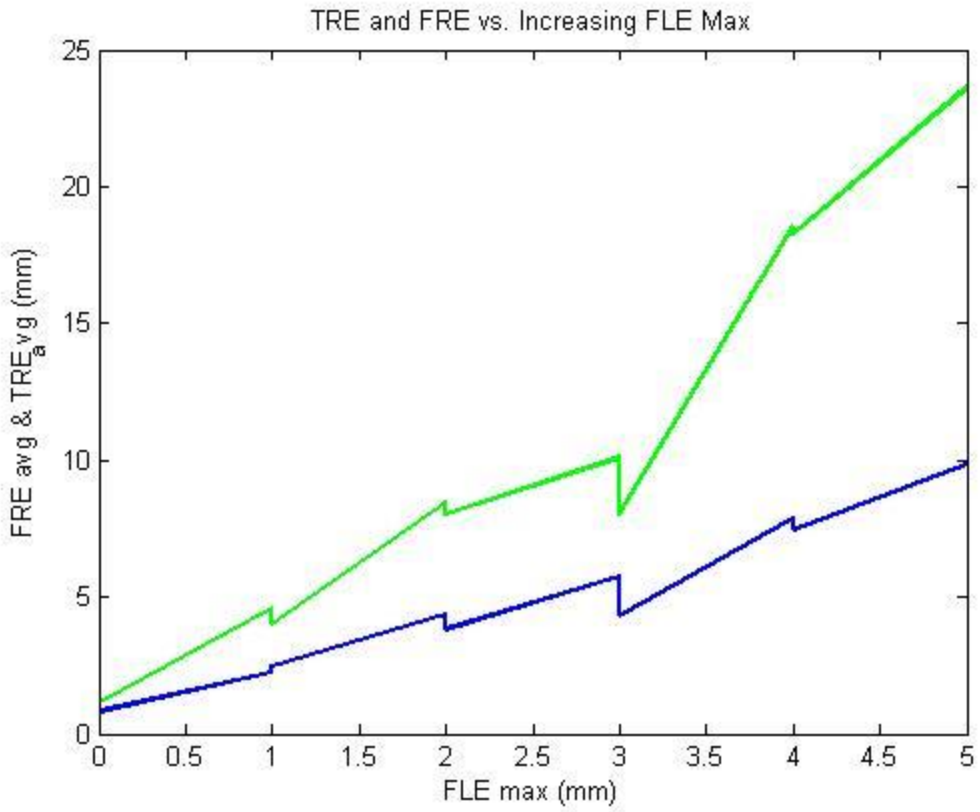

Figure 4: Comparing TRE and FRE for an increasing FLE_maximum

Test Results

Ground truth examples are labeled and included in the submission folder.

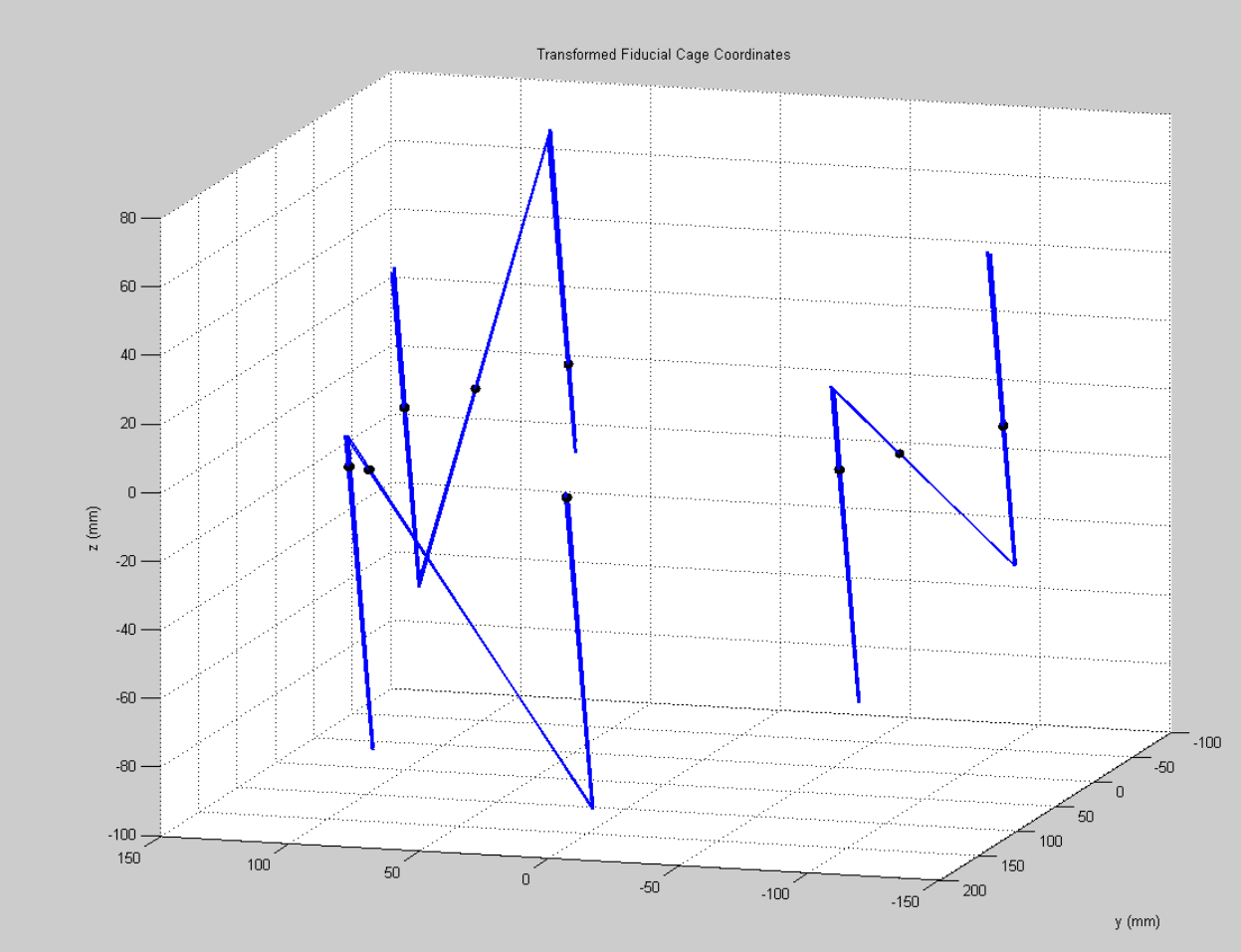

Figure 5: Shows the initial position of the fiducial cage, along with the re-transformed cage.

Transformer Test Output

```
EDU>> Transformer_Test

1. Identity Matrix

matrix =

     1     0     0     0
     0     1     0     0
     0     0     1     0
     0     0     0     1

points =

  -100  -100  -100   -50     0    50   100   100   100
   -50     0    50   150   150   150    50     0   -50
     0     0     0     0     0     0     0     0     0
     1     1     1     1     1     1     1     1     1

output =

    1.0000   -0.0000         0    0.0000
```

```
    0.0000    1.0000         0         0
         0         0    1.0000   -0.0000
         0         0         0    1.0000
```

2. 10 degree rotation, all axis

matrix =

```
    0.9698   -0.1710    0.1736         0
    0.2007    0.9646   -0.1710         0
   -0.1383    0.2007    0.9698         0
         0         0         0    1.0000
```

points =

```
  Columns 1 through 6

  -89.1128  -97.0158 -109.8074  -80.7719  -67.0493   18.6882
  -67.6327  -29.4441   32.3673  141.1837  143.6165  158.8163
         0         0         0         0         0         0
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000

  Columns 7 through 9

   89.1128  103.1801  109.8074
   67.6327   -0.3430  -32.3673
   -0.0000         0         0
    1.0000    1.0000    1.0000
```

output =

```
    0.9680   -0.1684    0.1860    0.1685
    0.2003    0.9651   -0.1686    0.8993
   -0.1512    0.2005    0.9680    0.2144
         0         0         0    1.0000
```

3. Translation X, Y, Z

matrix =

```
     1     0     0    10
     0     1     0     5
     0     0     1    15
     0     0     0     1
```

points =

```
   -90   -90   -90   -40    -5    60   110   110   110
   -45   -10    55   155   155   155    55    20   -45
     0     0     0     0     0     0     0     0     0
     1     1     1     1     1     1     1     1     1
```

output =

```
    1.0000   -0.0000         0   10.0000
    0.0000    1.0000         0    5.0000
         0         0    1.0000   15.0000
         0         0         0    1.0000
```

Simulator Test Results

```
EDU>> Simulator_Test

1. Identity Matrix

matrix =

     1     0     0     0
     0     1     0     0
     0     0     1     0
     0     0     0     1

points =

  -100  -100  -100   -50     0    50   100   100   100
   -50     0    50   150   150   150    50     0   -50
     0     0     0     0     0     0     0     0     0
     1     1     1     1     1     1     1     1     1

matrix =

    0.9361   -0.3407    0.0872         0
    0.3516    0.9000   -0.2578         0
    0.0094    0.2720    0.9623         0
         0         0         0    1.0000

2. X, Y, Z rotation (15, 5, 20)

points =

  Columns 1 through 6

  -75.2587  -93.8050 -111.7942 -101.5665  -94.0755   -8.0401
  -84.0506  -34.6666   13.2335  128.2219  131.0580  163.6305
    0.0000         0         0         0    0.0000         0
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000

  Columns 7 through 9

   75.2587   93.0282  111.7942
   84.0506   36.7351  -13.2335
         0         0   -0.0000
    1.0000    1.0000    1.0000

3. 45 degree rotation in Z axis

matrix =
```

```
    0.7071   -0.7071         0         0
    0.7071    0.7071         0         0
         0         0    1.0000         0
         0         0         0    1.0000


points =

  Columns 1 through 6

  -35.3553  -70.7107 -106.0660 -141.4214 -106.0660  -70.7107
 -106.0660  -70.7107  -35.3553   70.7107  106.0660  141.4214
         0         0         0         0         0         0
    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000

  Columns 7 through 9

   35.3553   70.7107  106.0660
  106.0660   70.7107   35.3553
         0         0         0
    1.0000    1.0000    1.0000
```

Analyzer Output

```
EDU>> Analyzer

Random input matrix to Simulator function

xyz_m =

    0.5768   -0.7965   -0.1816  154.1666
    0.8127    0.5820    0.0284  118.2565
    0.0831   -0.1639    0.9830         0
         0         0         0    1.0000

Output Matrix from Transformer function

HTM_out =

    0.5779   -0.7968   -0.1765  153.8439
    0.8124    0.5822    0.0316  118.4674
    0.0775   -0.1616    0.9838   -0.1330
         0         0         0    1.0000
```

Standard deviation

```
EDU>> Analyzer

FRE_std =

    6.2855

TRE_std =

    2.7290
```