ENME489C/ENME808M: Problem Set 8
Medical Imaging

Prof. Axel Krieger

Fall 2017

Due Date: Wednesday 11/8 11:59 PM

November 1, 2017

1 Problem Statement

In this problem set, we will be analyzing a 3D MRI scan with three targets (think suspicious tumor locations in the brain) and three fiducial markers (think fiducial markers on the skull). Your task is to identify the fiducials and targets and find the metric target locations in the frame spanned by the fiducial markers. You will accomplish this by a) loading the 3D MRI scan into a medical imaging software "3D Slicer", b) finding the slices and slice locations that contain the targets and fiducials, c) exporting these slices into Matlab, d) finding the targets and fiducials in pixel coordinates in Matlab, and e) finally finding the metric coordinates of the targets in the fiducial frame. To check your results, you will compare your results with design drawings of the fiducial and marker brackets. In future problem sets, you will use this registration between fiducials and targets to steer a needle into the targets (think for biopsy, ablation, drug delivery) with the help of a camera imaging the fiducial markers.

Figure 1 shows a picture of the bracket with the three targets and the three fiducials (yellow color), which we will be using for this problem set and also for your final project. This bracket was immersed in a water bath and imaged with an MRI scanner. The DICOM images from the MRI scan are provided to you in the `dicomimages` folder. One thing for you to note is that targets normally are not visible and the MRI helps us to bring these targets to light. So, we can assume that we have a layer of skin and skull on top of our target points and the three rings are only visible in MRI images. Your task is to identify the 3D position of the center of the targets (rings) with reference to a co-ordinate frame defined by the three fiducials. Since, only fiducials are visible during the operative phase, it is important to accurately determine the position of such targets with reference to the fiducials.

2 Locating the correct slices

For processing the provided DICOM volume, we will use a software called **3D slicer**. 3D Slicer is an open source software platform for medical image informatics and three-dimensional visualization. The software can be downloaded from here. We will use this software to identify

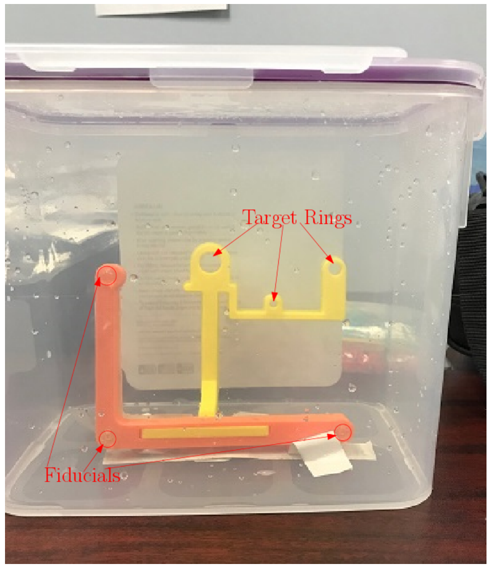
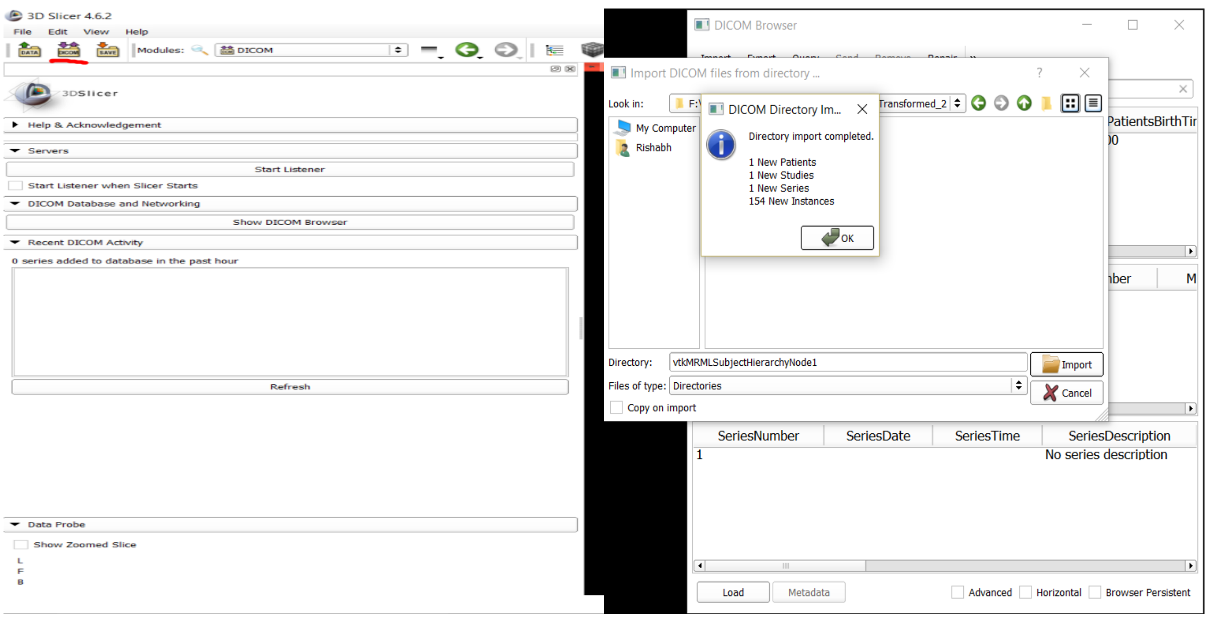


Figure 1: Picture containing three targets and three fiducial markers in a water bath.



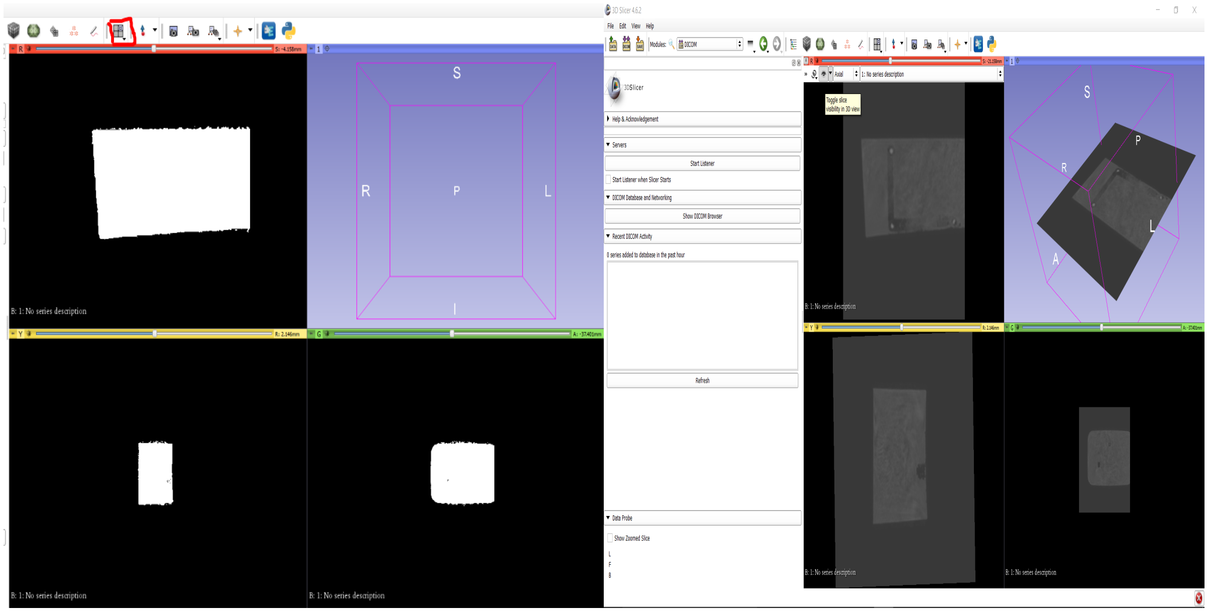
(a) Load Dicom

(b) Import volume

Figure 2: Loading Dicom Images in Slicer.

and export the correct slices containing the markers and fiducials. 3D Slicer has many advanced image display, image processing, and image guidance capabilities. Please follow the documentation at the3D Slicer website if you want to learn more. For the purpose of the current problem set you may follow these instructions:

- First step is to import the MRI volume. Click on the load DICOM button to do this. Then click on import and select the folder `dicomimages`. Figure 2a and 2b shows



(a) Views after importing

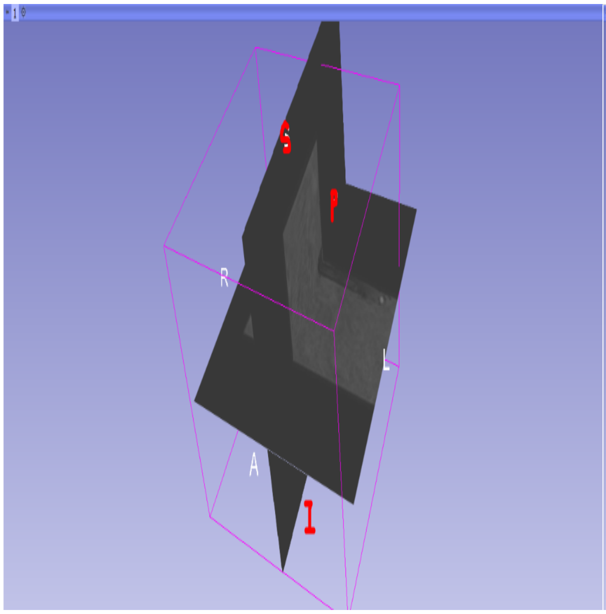
(b) Views after gray level adjustment

Figure 3: Adjusting gray scale and viewing different slices in 3D Slicer.

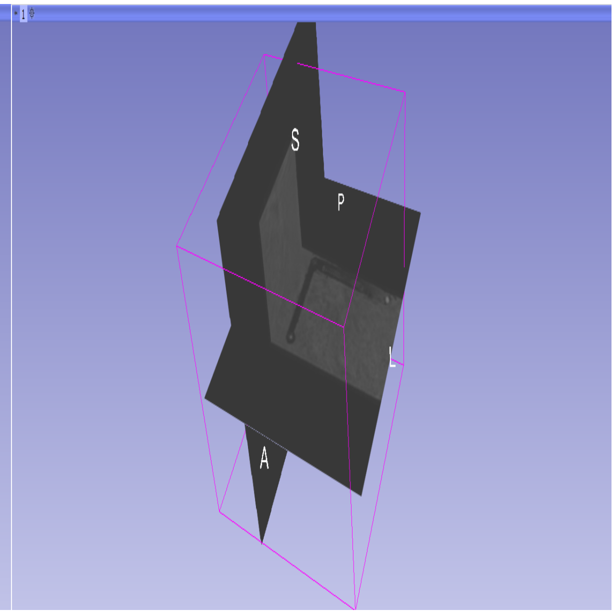
you the steps.

- After you import, you should see the view as shown in figure 3a. If you have a different scene layout, you can change it using the option shown using red box. The imported slice initially has only two color levels. We can control the amount of gray levels (called window and level) we want by left clicking and sliding the mouse in any view from left-right and bottom-up. Slicer's Volumes Module provides a "Display" interface panel for making more precise adjustments. Once, you adjusted the gray scale to see the water bath and bracket, slide the slidebar at the top of your image panel to scroll through slices (you can also use the wheel on your mouse) you will be able to see some gray images as shown in figure 3b. Also, you can enable the 3D view with a toggle option, shown in 3b, to display where that particular slice is located in the 3D volume.

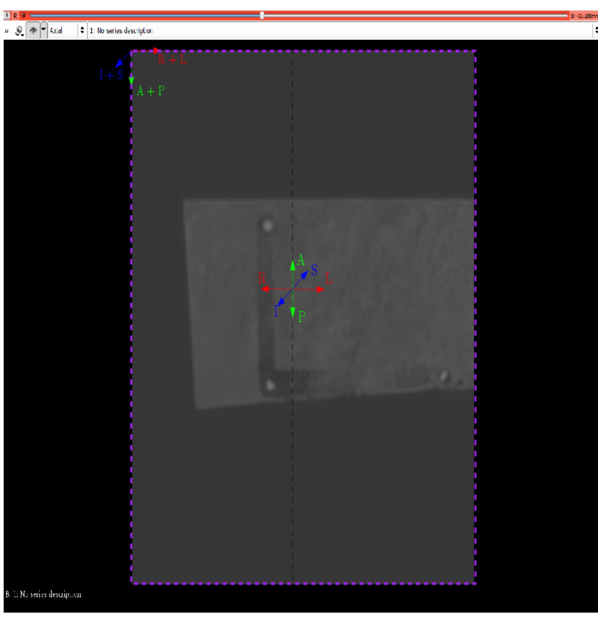
- A quick look at the 3D view as shown in figure 4a displays how our volume is arranged in 3D space. You will now need to find and export the slice that contains the fiducial markers and the slice that contains the three targets. The additional important pieces of information you need for metric registration are the field of view (FOV), pixel spacing, slice number and thickness of each slice. This information is provided with the meta data of the DICOM images, stored in the DICOM header:
  - A-P and I-S directions correspond to **240x240** pixels. Each pixel size is **1.033 mm x 1.033 mm**.
  - L-R direction correspond to the scanning direction. In this direction we have **154** slices and each slice is **1.4 mm** thick.



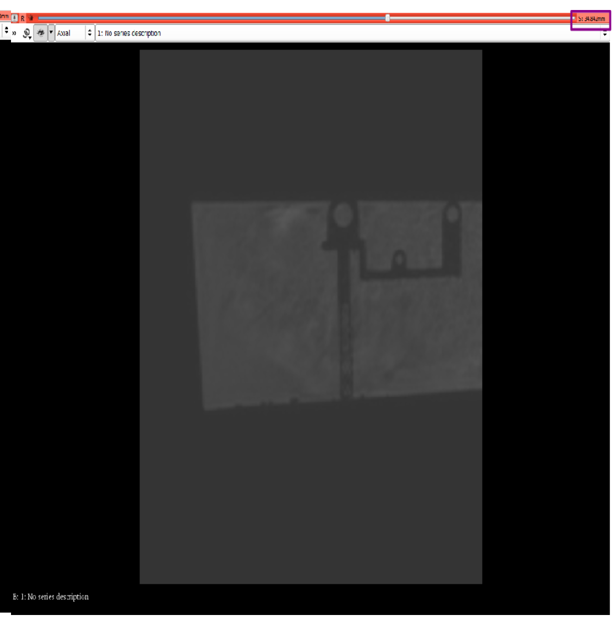
(a) L-R (Left-Right), A-P (Anterior-Posterior), I-S (Inferior-Superior)



(b) Sliding along the L-R axis



(c) Viewing only the red slice. Slice plane is the window shown in purple color



(d) Only slide the trackbar at the top to get the slice containing target rings. The depth value of the slice is obtained by looking at the value inside the purple box

Figure 4: Making sense of the position of the model in the MRI scans

The view we are concerned about for finding the targets and markers is the axial direction displayed in the Red Slice. You can only show this slice by changing the scene layout option, as shown before. Taking pointers from figure 4c and using the meta data above you should calculate and write down the length and width of each slice in mm as seen in the red slice. Follow these steps to get the correct two slices containing the markers and targets and also obtain the distance between those two slices.

- Start with the slice containing the three bright fiducial markers. Make sure that you adjust your gray levels such that the markers are clearly visible. Also make sure that the outer gray window is clearly visible, which defines the slice plane (shown with a purple dashed box in figure 4c) from the black background. Once you get the desired gray level and window settings, save this slice using capture screenshot option and then using File>save option.
- Scroll to the slice that contains the three target rings (pick the center slice). **DO NOT** zoom or pan inside the slice plane from your last setting. This would lead to incorrect position values of the centroid positions of the rings. You may again use left click and slide left-right and bottom-up to adjust the gray levels for this slice. Just make sure the outer gray window which represents the slice is visible as shown in figure 4d. Again take a screenshot and export this image. Calculate and write down the distance of this slice containing the three targets to the slice containing the three markers, using the distance value next to the slidebar. This position is highlighted in a purple box next to the slidebar in figure 4d.

At the end of this section you should have your screenshots of the fiducial and target slices for further processing, the dimensions of each slice in mm, and also the depth measurement from the fiducials to the centroids of the target rings. Write these values in your Report [30 points].

3 Getting pixel co-ordinates of the targets and fiducials

Now, shift to the MATLAB environment for processing the images that you exported. The goal of this section is to find the marker and fiducial positions in pixel coordinates. Follow the comments in the starter code and tips from the lecture slides on how you can create binary images and get the necessary centroid positions. You will use the following fundamental operations on your two image in MATLAB:

- Loading an image [`imread`]
- Noise removal [`medfilt2`]
- Contrast adjustment [`imadjust, histeq`]
- Image sharpening [`imsharpen`]
- Image thresholding [`imbinarize`] or inequality operators
- Morphological cleaning [`imdilate, imerode`]

- Blob Analysis [`regionprops, bwlabel`]

You should obtain your positions in pixel co-ordinates for the fiducials in the first image and the center of the rings in the second image. Write your code in `findCentroidsFiducial.m` and `findCentroidsTargets.m`, for finding the respective points. You should put in your report a final image with detections showing contours drawn over your detected fiducials and an image with contours over the target rings highlighted in the image [40 points].

4 Expressing metric target locations in fiducial frame & Validation

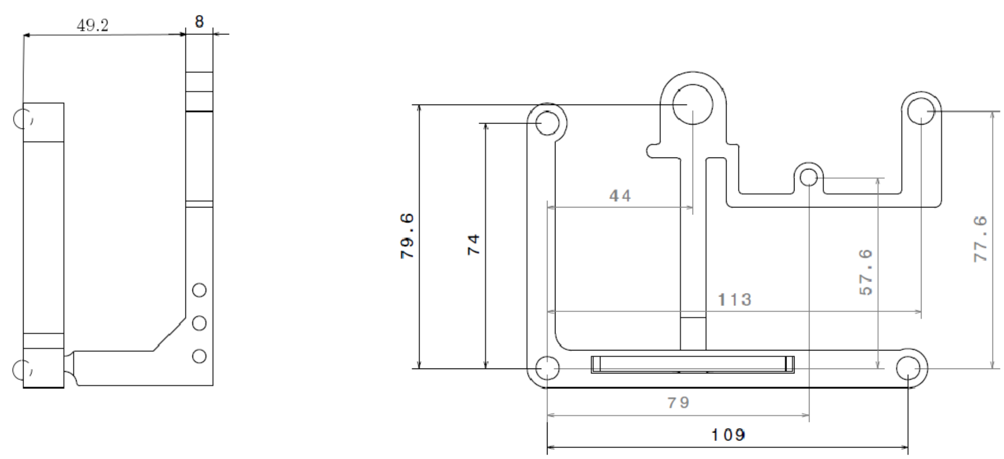


Figure 5: Values ground truth (in mm)

Using the information on the slice and pixel dimensions obtained from the 3D Slicer section, and the pixel co-ordinates of the target and fiducial centroid positions that you just found, you should express the metric positions for each of the target and fiducial centroid positions in mm in a co-ordinate frame of your choosing. Report your calculation and your answers. Once you know the 3D position of the fiducials and also the target points, you can express the position of the target points in the fiducial frame. Define a right-handed co-ordinate frame using the three fiducials and transform the target points in this frame. Also, you should validate your values with the ground truth values as shown in figure 5. Sketch your frame assignment and show the calculation for this part in your report [30 points].

5 For Grad Students

In the previous sections we assumed that the orientation of the imaging volume is perfectly aligned with the fiducial and target bracket. However, as you can see when viewing the MRI volume in 3D Slicer, not all the fiducials are clearly visible in the same slice. The center of each fiducial is located on different slices, due to a mis-alignment of the imaging volume and fiducial bracket. In this section your task is to find and export a separate slice for each fiducial corresponding to the three fiducial centers. You will then need to use this information to more accurately estimate the metric position of the centroids of the target rings in the fiducial frame [20 points].

6 Resources

- Slicer
- Reading Images
- Noise Removal
- Constrast Adjustment
- Image sharpening
- Morphological filtering
- regionprops
- An example of Image Segmentation of a cell
- Beekley Medical Markers

7 Submission

A single zip file containing the following items:

- `findCentroidsFiducial.m`
- `findCentroidsTargets.m`
- Selected images for the fiducial and the target rings
- A report containing your calculations for each of the sections as mentioned above. Put all your plots that you draw on images in this report.

Make sure your code runs when your submission folder is chosen as the working directory inside MATLAB.