Information Processing for Medical Imaging
MPHY0025 – 2020/2021

Registration exercises 2
MATLAB version

You have been provided with some utility functions for use in these exercises (some of these are the same as used in exercises 1 but there are also some additional functions included):

dispImage.m

defFieldFromAffineMatrix.m

resampImageWithDefField.m

affineMatrixForRotationAboutPoint.m

calcSSD.m

calcMSD.m

calcNCC.m

calcEntropies.m

as well as a template script for your solutions:

templateScript2.m

You should look at the code for the utility functions and make sure you understand what they do and how they work.

You have also been provided with the following 2D images:

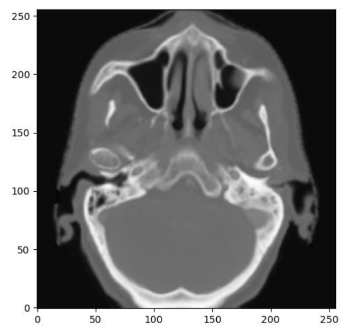
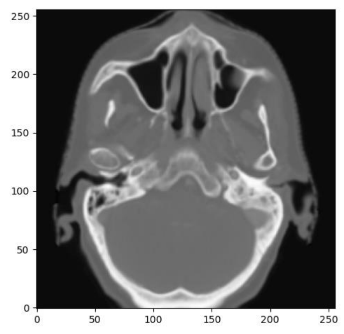
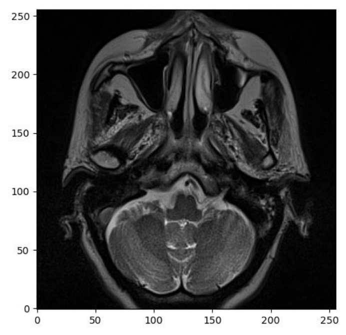
ct_slice_int8.png – an axial CT slice of a head, stored as unsigned 8-bit integers

ct_slice_int16.png – the same axial slice CT slice, stored as unsigned 16-bit integers

mr_slice_int16.png – the corresponding axial MR slice, stored as unsigned 16-bit integers

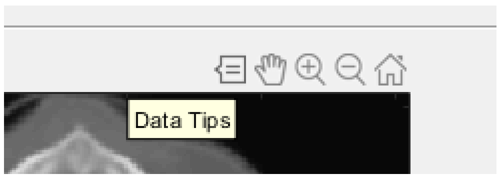
Similarity measures

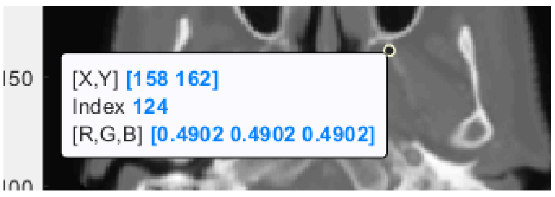
The template script includes code to load in the three 2D images. Add code to the template script to display the data type of each image and check these match the expected data types. Now add code to the template script to convert the images to double, reorientate them into 'standard orientation', and display each image in a separate figure using the `dispImage` function. The images should appear as shown on the next page.

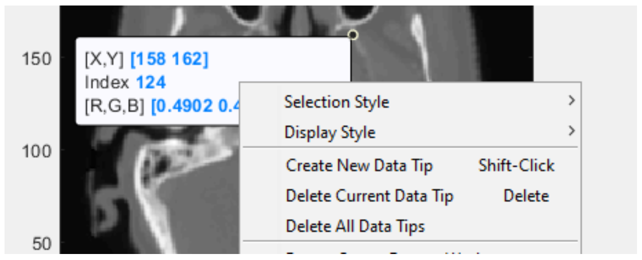
You should notice that the two CT images appear exactly the same, but if you examine the actual values in the images you will see that the images use different intensity ranges. In the 16 bit image, the intensity values correspond to Hounsfield Units (or rather Hounsfield Units + 1000, since air has a value of -1000, but the image cannot contain negative values as it is stored as unsigned integers), but in the 8 bit image the values have been scaled as the image can only contain values from 0 to 255.

You can inspect the intensity values by first moving the cursor over the image in the figure. This will make several icons appear above the image, the left most of which is called *Data Tips* (the name appears when you move your cursor over the icon, but the cursor is missing from the image below). When you move the cursor over the image after selecting *Data Tips* you will see the cursor change to a cross, and if you click on the image it will tell you the x and y coordinates and intensity (index) of the point you click on (it will also tell you the RGB values which specify the colour and brightness of the pixel in the current display). To remove the data tip once you have finished inspecting the image, right click on the white box with the info in and a menu will popup from which you can select *Delete Current Data Tip* or *Delete All Data Tips.*





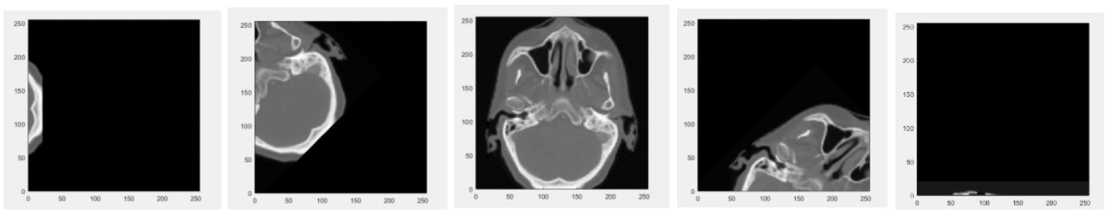
```
[X,Y] [158 162]
Index 124
[R,G,B] [0.4902 0.4902 0.4902]
```



```
[X,Y] [158 162]
Index 124
[R,G,B] [0.4902 0.4
```

Selection Style
Display Style
Create New Data Tip Shift-Click
Delete Current Data Tip Delete
Delete All Data Tips

The template script contains some code to rotate each of the images between -90 degrees and 90 degrees, in steps of 1 degree. Edit the code so that on each iteration of the loop it uses the `affineMatrixFromRotationAboutPoint` function to create an affine matrix representing an anti-clockwise rotation by theta degrees about the point 10,10 and uses the `defFieldFromAffineMatrix` function to create the corresponding deformation field. Then resample each of the 3 images using the `resampImageWithDefField` function and display the transformed 8-bit CT image using the `dispImage` function. If this has been implemented correctly the image should appear to rotate clockwise, starting with a rotation of -90 degrees (so mostly being ‘off to the left’ of the original image) and finishing with a rotation of +90 degrees (so mostly being ‘off the bottom’ of the original image), as shown in the intermediate images below:



Make sure you understand why the image appears to rotate clockwise when the function produces an affine matrix representing an anti-clockwise rotation.

Note, the default padding value of NaN should be used when resampling the image so that pixels from outside the original images are ignored when calculating the similarity measures below. Now modify the template script so that on each iteration of the loop it calculates and stores the SSD between:

1) The original 16-bit CT image and the transformed 16-bit CT image
2) The original 16-bit CT image and the transformed 8-bit CT image
3) The original 16-bit CT image and the transformed MR image
4) The original 8-bit CT image and the transformed 8-bit CT image

Now rerun the cell with the for loop (you may want to comment out the lines that display the image and pause so that the code runs faster). Once you have done this run the next cell in the template script that plots the SSD values on the y-axis against the angle theta on the x-axis, for each of the four cases above. The plots should look like those on the next page.

Note that:

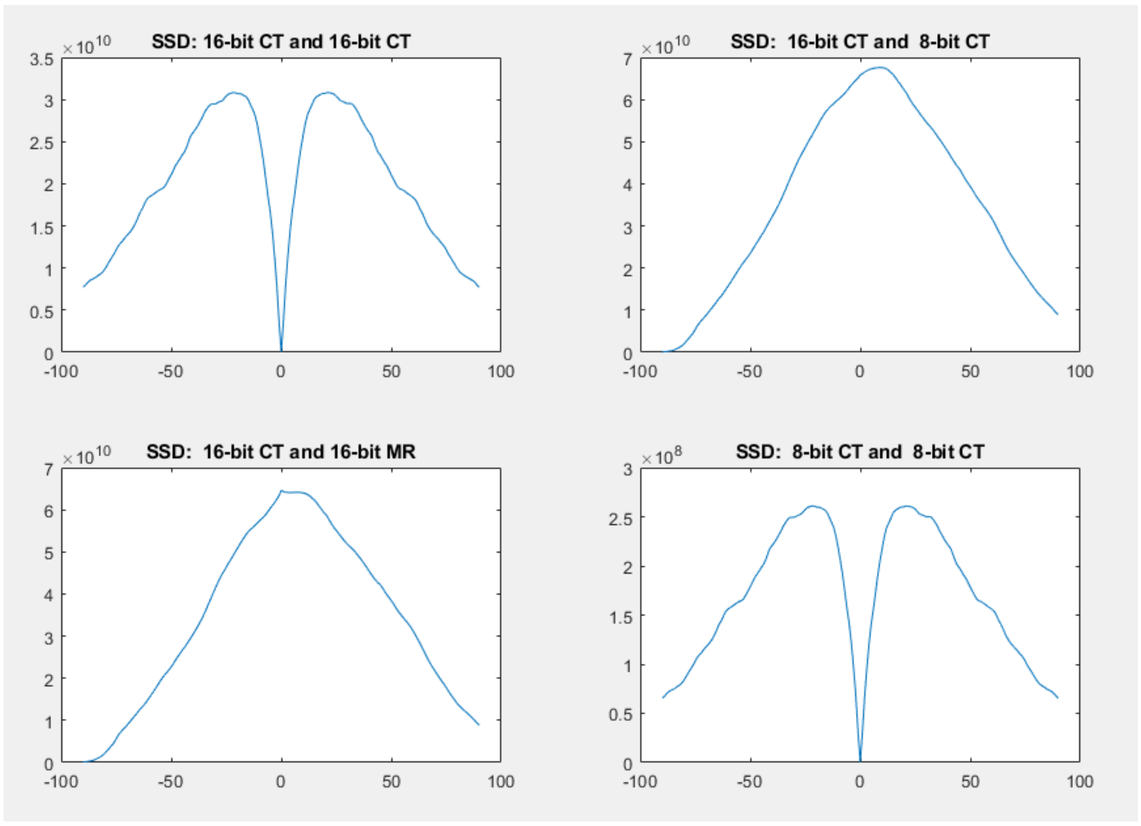
SSD reaches a minimum (of 0) for cases 1 and 4 when the images are in alignment.

For cases 2 and 3 SSD does not have a minimum when the images are aligned.

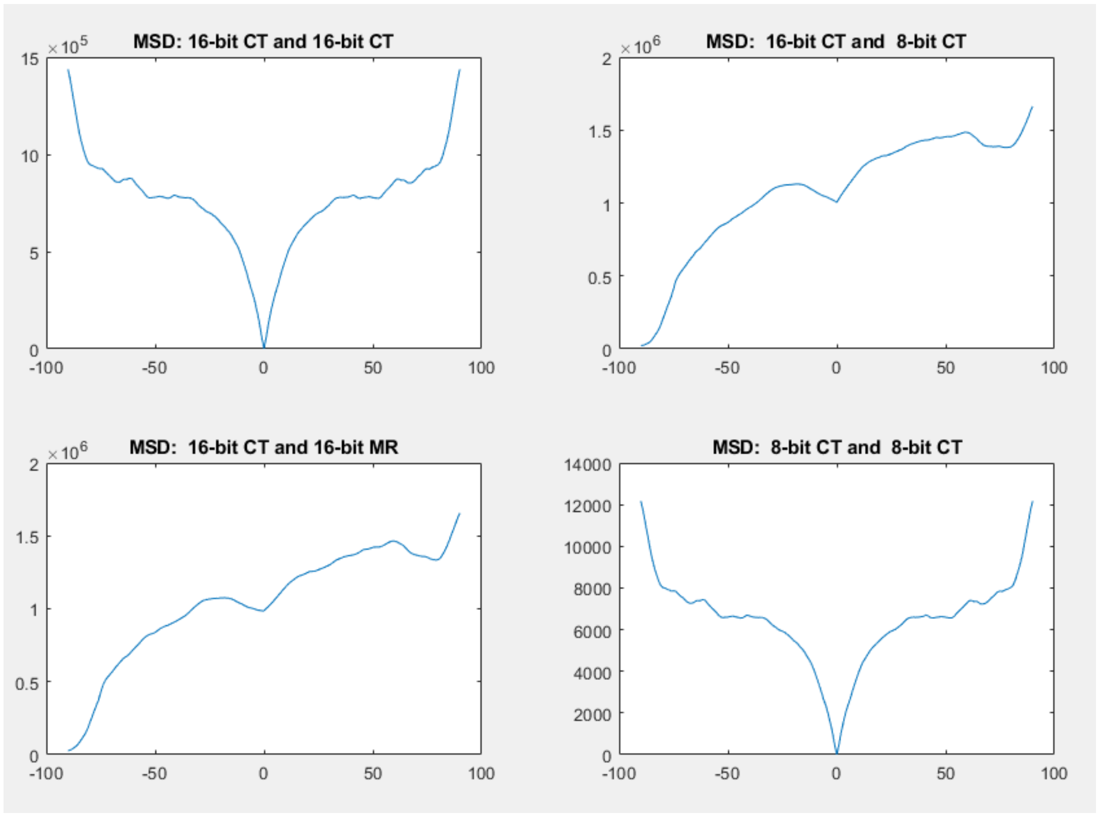
For all cases the SSD decreases as the overlap between the images decreases.

Although the shape of the SSD curve for cases 1 and 4 is the same, the values of the SSD are different by 2 orders of magnitude.

Make sure you understand why you get these results. If you are not sure ask me or one of the PGTAs in the lab session.



Now edit the code in the template script so that it rotates the images as above but calculates the MSD instead of the SSD at each iteration, and then plots the MSD values. The plots should look like those below:



Make sure you understand why:

The MSD for cases 1 and 4 does not decrease as the amount of overlap decreases.

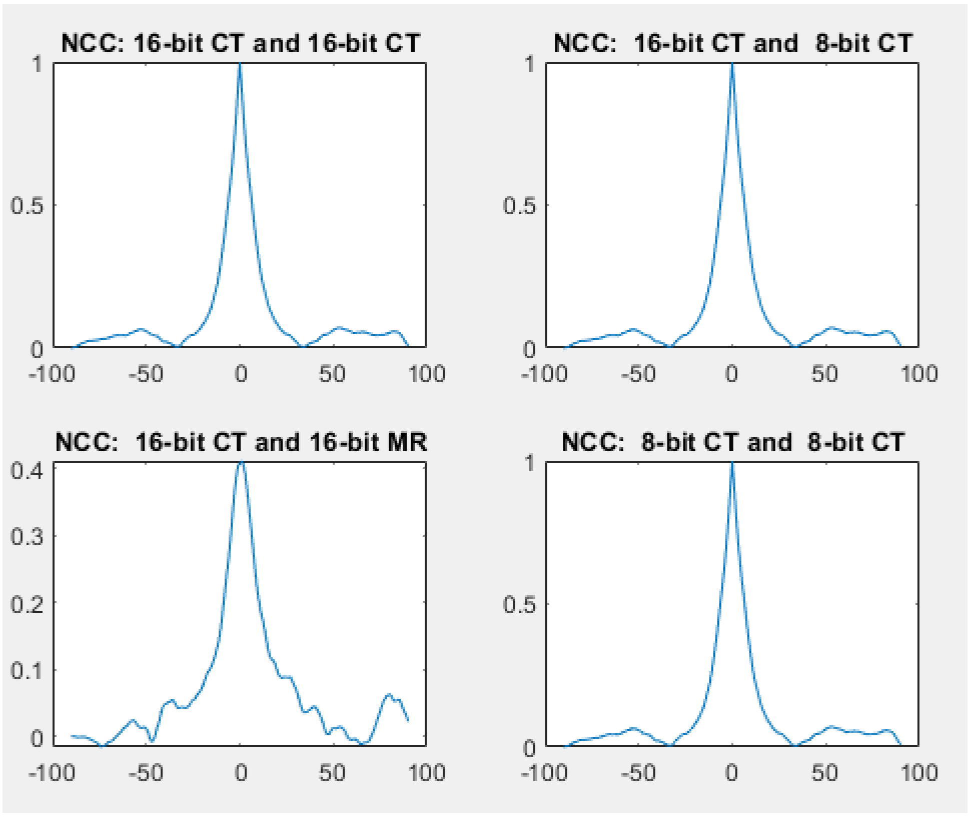
The shape of the MSD curves for cases 1 and 4 are the same but the values are larger for case 1.

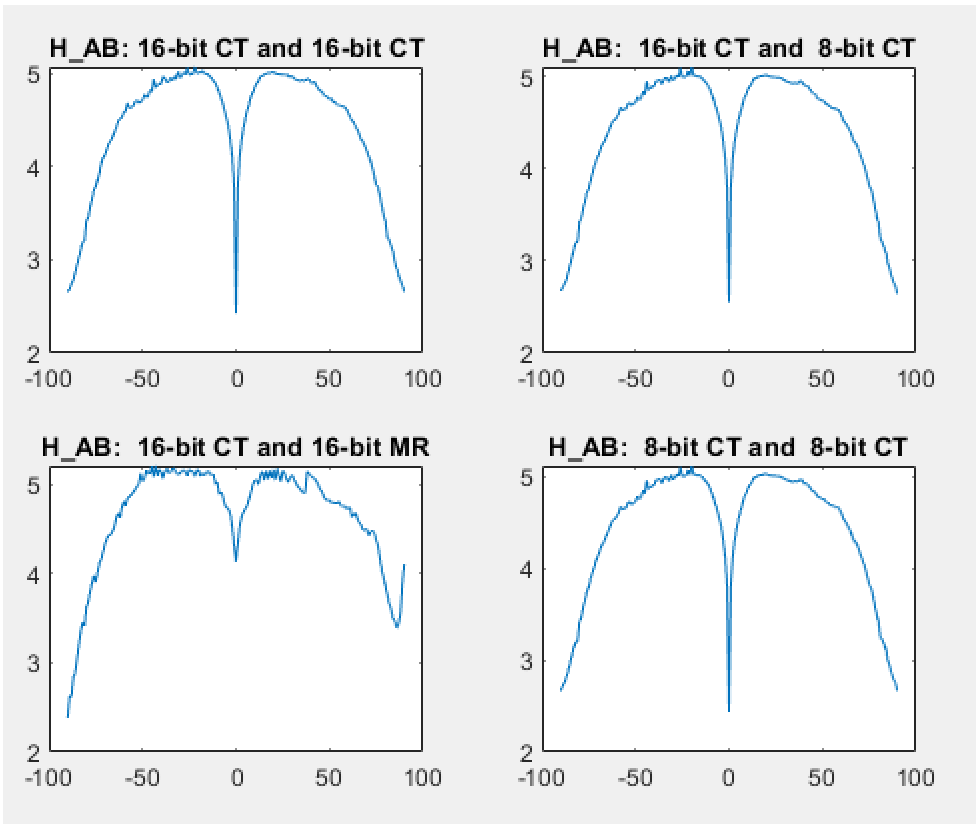
The MSD values for cases 2 and 3 are lower for negative values of theta and higher for positive values (this one is a bit tricky!).

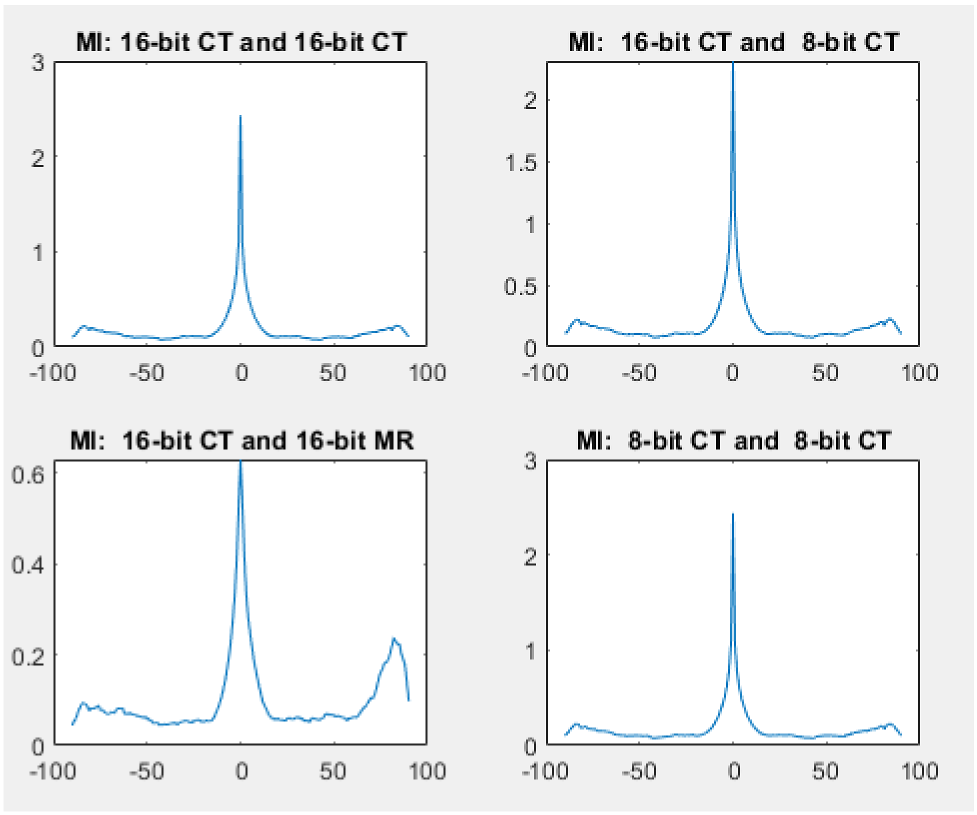
Now edit the template script to use the `calcNCC` and `calcEntropies` functions to calculate the Normalised Cross Correlation (NCC) and the joint and marginal entropies (H_AB, H_A, and H_B) instead of the MSD/SSD at each iteration. Add code to the template script to calculate the Mutual Information (MI) and Normalised Mutual Information (NMI) from the entropy values, and plot the results for NCC, H_AB, MI, and NMI. The plots you get should look like those below and on the following pages.

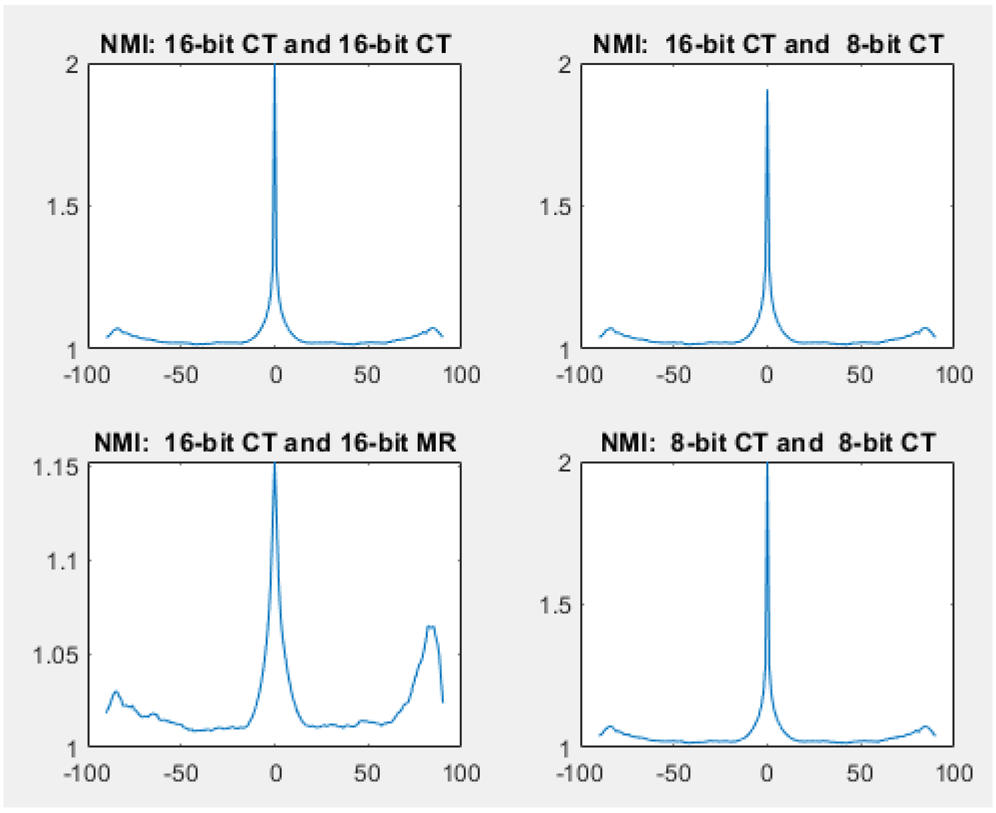
Do the different measures perform as expected for the different cases? Based on these results, which measures are suitable for registering the different pairs of images? Does this agree with what you were taught in the lecture?

Make sure you understand all the results you get.




H_AB: 16-bit CT and 16-bit CT
H_AB: 16-bit CT and 8-bit CT
H_AB: 16-bit CT and 16-bit MR
H_AB: 8-bit CT and 8-bit CT
2
3
4
5
-100
-50
0
50
100


MI: 16-bit CT and 16-bit CT
MI: 16-bit CT and 8-bit CT
MI: 16-bit CT and 16-bit MR
MI: 8-bit CT and 8-bit CT
0
1
2
3
0.5
1.5
0.2
0.4
0.6
-100
-50
0
50
100


NMI: 16-bit CT and 16-bit CT
NMI: 16-bit CT and 8-bit CT
NMI: 16-bit CT and 16-bit MR
NMI: 8-bit CT and 8-bit CT
2
1.5
1
1.15
1.1
1.05
-100
-50
0
50
100