Assignment #3

- **This is a group assignment. You have been assigned to a group.**
- **Submit your work via MyCourses. One submission per group, and everyone will get the same grade.**
- **Submit your code scripts (with adequate comments!), and your results and observations. No need to submit code for external libraries that you may use, but indicate them in the comments.**
- **If you are struggling with coding within your group, please let me know and I can make adjustments.**

1. For this question, write a software script to solve the problems. Use comments in your script so that we can follow what you are doing. Comment what you see from the output of your script, either in the comments of the script itself or in a separate file.

   Note: you can use any language you want, but MATLAB and Python are most likely to have the built-in functions and/or available libraries to perform the work without coding everything from scratch.

   The dataset has the following properties:
   Angle of projections: 0 to 179 degrees in 1-degree steps
   Image size: 256×256
   μ (water) = 0.02059 mm^{-1}
   μ (bone) = 0.05983 mm^{-1}

   a. Load the provided parallel beam projection data (in MATLAB use the `load` function on the `mdph607_projection_data.mat`). Alternatively, load the data from the CSV file (if working in something other than MATLAB). Plot the sinogram data for both datasets.

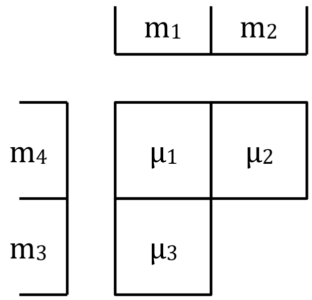
   b. Using a function for backprojection (`iradon` in MATLAB), compute the reconstructed image from the 2D sinogram of dataset 1 and show your images. Reconstruct 3 images: (i) the laminogram, (ii) FBP using the ramp filter, and (iii) FBP using another filter. Convert your image to CT numbers (HU). Discuss your observations. Does the choice of filter matter in this case?

   c. What happens if you reduce the number of projections while maintaining the same range of projection angles (*i.e.* select every third column of the sinogram, *i.e.* in the angle direction)?

   d. What happens if you reduce the range of angles covered by the projections (*i.e.* reduce the number of projections by keeping only the first 1/3 of the columns of the sinogram, *i.e.* in the angle dimension)?

   e. Using a function for backprojection (`iradon` in MATLAB), compute the reconstructed image from the 2D sinogram of dataset 2 and show your images. Reconstruct 2 images: (i) FBP with the ramp filter, and (ii) FBP with another filter. Convert your image to CT numbers (HU). Discuss your observations. What is different from dataset 1? Does the choice of filter matter in this case? Hint: plot the histogram of pixel values to compare the images quantitatively.

2. Consider the simple X-ray CT system described below, with 3 image pixels ($j = 1,2,3$) and 4 projection bins m_i ($i = 1,2,3,4$). Assume all the image pixels have length = 1 mm.



You are given a set of X-ray intensity measurements:

$t_i = \{192, 192, 196, 188\}$ for the transmitted intensity with object

and

$b_i = \{200, 200, 200, 200\}$ for the background intensity (without the object)

Implement the SART reconstruction algorithm in your preferred programming language.

What is the estimate of the image after one iteration of the algorithm?

Then, allow the reconstruction to run until conversion (*e.g.* such that the estimate of the image does not vary or varies very little between successive iterations). What is your reconstructed image?

Hints:
Start by writing down the system matrix $\mathbf{X} = \{x_{ij}\}$, assuming that only vertical and horizontal parallel ("x-ray") projections are collected.
Compute the quantities that are re-used at every iteration, $\sum_{i=1}^{I} a_{ij}$ and $\sum_{j=1}^{J} a_{ij}$, only once.