ECE 5206 Spring 2024 Homework Set 2
Due: 5:00PM Tuesday Feb 20, 2024
Deliver to CL 383 if not submitted via email

Choose **one** of the following six Matlab experiments for this homework assignment. You have to write your own reconstruction code (one per team is fine), *i.e.* using the built in Matlab function `iradon()` will not be considered a strategy that produces credit for the project. The data for all experiments can be found on the Carmen site under

`Modules` $\rightarrow$ `Homework/Computer Projects` $\rightarrow$ `Project 2 Data`

and should be saved as a file to your own directory where you use Matlab.

Once in your directory, the data can be loaded into Matlab using the command:

```
load('projs.mat')
```

This will create a 144×513 *sinogram* array called p in which each row is a projection through an object at a specific angle, ϕ. The 513th element of each row is always zero-valued. The extra element in each row was added so that the number of columns is odd for the `imrotate` command, which I used to generate the set of projections. The *origin* of each projection is the middle (257th) element. This corresponds to projection lines through the (257,257) element in the original 513×513 object array used to generate the projections. Each row represents a different angle in 1.25^o increments, starting at 0^o and continuing in the counterclockwise direction up to 178.75^o. In the original image notation, the positive sense of the y (vertical) direction is the top of the image. Note this is opposite of the usual sense for indexing arrays in Matlab! *When using FFT or IFFT commands (including the 2-D versions) make sure that you use array sizes that are powers of 2. Because the 513th column is all zeros in* p*, you can do this by truncating the 513th element in the* x'*-domain.* If you are not using FFT or IFFT (for example when using convolution filtered backprojection) you do not need to truncate the rows to 512 elements.

In all cases, include both quantitative and qualitative assessments of the effects observed. If you show me a correctly reconstructed image in person or via email (only email jpg format of image), I can email you the "perfect" image array I used to generate the projections if you would like a ground-truth image for numerical comparison.

Turn in only ONE of the following experiments (do not mix them):

1.) (80pts) **Comparison of Resolution of Data for Filtered Backprojection:** Write Matlab programs to perform filtered backprojection using either the Ram-Lak or Shepp-Logan filters and performing filtering in either the ω_x'-domain or in the x'-domain. Experiment with changes in the spacing of the angles used (for example use only odd numbered rows of data) and experiment with the x' sample spacing (for example use only odd numbered elements in each row). Note that if you eliminate the column containing the origins of the projections (513th in the original projection data array), you will have problems with the reconstruction. Discuss the effects of lowering the data resolution in each of these two ways.

2.) (80pts) **Comparison of Filter Impulse Response Length for Filtered Backprojection:** Write Matlab programs to perform filtered backprojection to compare the Ram-Lak and Shepp-Logan filters, performing filtering in the x'-domain. Experiment with changes in the length of the impulse response vector used in the convolution. Discuss the effects of the length of the impulse response used on the image reconstruction fidelity. In your opinion, is there a length of the impulse response beyond which further increase in length does not provide a noticeable improvement in reconstruction fidelity? Briefly justify your answer.

3.) (80 pts) **Comparison of ART and either direct or filtered backprojection:** Write programs to perform one of the ART methods described in the lecture and compare its performance to either the direct or filtered backprojection method reconstruction. Items for comparison include computational speed and fidelity of the reconstruction compared to the ideal image.

4.) (80pts) **Incomplete angle information reconstruction:** Experiment with the quality of reconstruction when there are missing projections (a group of missing neighboring rows in p). Compare direct 2-D inverse FFT reconstruction and filtered backprojection reconstruction (using either Ram-Lam or Shepp-Logan and either ω_x'-domain or x'-domain filtering). Compare the quality of the reconstruction versus having the full set of projections. Does it matter whether the missing rows are replaced with zeros or simply omitted (but remembering the angles associated with the remaining rows)? Is the quality different in these cases between the direct and filtered backprojection approaches? Explain.

5.) (80pts) **Bad detector information reconstruction:** Experiment with the quality of reconstruction when there are columns in projections incorrect due to a failing photodetector in the scanner. For example an entire column might be replaced with zeros or some constant to simulate a malfunctioning detector for that column. Compare direct 2-D inverse FFT reconstruction and filtered backprojection reconstruction (using either Ram-Lam or Shepp-Logan and either ω_x'-domain or x'-domain filtering). Does the particular column that malfunctions have a significant effect?

6.) (80pts) **Noise Degradation of the Data and Effects on Image Quality:** Include additive white gaussian noise of various strengths into the set of projections given. Experiment with root mean squared (RMS) noise levels relative to the peak projection intensity and observe the effects on the reconstructed image. Compare the direct 2-D inverse FFT method and one of the filtered backprojection methods.