EEE 473/573 Medical Imaging – Fall 2024-2025
Homework 3
Due 13 November 2024, Wednesday at 23:59

GUIDELINES FOR HOMEWORK SUBMISSION

1. Submit your solution via Moodle. No submission via e-mail (all email submissions will be discarded).
2. Submit a single PDF file. Other file types will not be accepted. If there are any handwritten parts, you can scan them (make sure they are legible) and insert into the PDF file. No partial credits to unjustified answers.
3. This is a Turnitin submission. The Turnitin system requires the submitted file to contain at least 20 words in it. If you are submitting a Word file with scanned pages only, the file may be rejected by the system. You can type your name multiple times at the beginning of the file to overcome this problem.
4. For the part labeled as "MATLAB Question", you can choose to use MATLAB or other software (e.g., Python). Make sure to include the relevant codes at the end of the PDF file to be submitted. If your codes are missing, that question will NOT be graded.
5. Submission system will remain open for 1 day after the deadline. No points will be lost if you submit your assignment within 12 hours of the deadline. There will be a 50% penalty if you submit after 12 hours but within 24 hours past the deadline. No submissions beyond 24 hours past the deadline.

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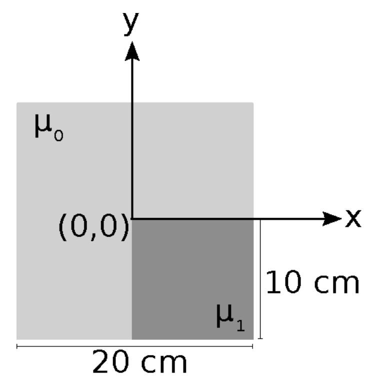
1) The square object shown on the right has 20 cm x 20 cm dimensions. It has two different compartments with linear attenuation coefficients of $\mu_0 = 0.1\ cm^{-1}$ and $\mu_1 = 0.2\ cm^{-1}$. This object is imaged with a CT scanner using parallel ray geometry.



a) Find and sketch $g(l, 0^o)$.

b) Find and sketch $g(l, 90^o)$.

2) For the 2D function $f(x,y) = e^{-x^2}$, find the 2-D radon transform (i.e., the projections $g(l,\theta)$). Simplify your answer as much as possible. **Hint:** Use the Projection-Slice theorem.

3) Given the projections, $g(l,\theta) = sinc(l - a \cdot sin\theta)$, find the associated object, $f(x,y)$. Simplify your answer as much as possible. **Hint:** Use the Projection-Slice theorem.

4) MATLAB Question: As we covered in Chapter 6, the process of taking the projections of a 2D function is also called "Radon Transform", and the inverse process of reconstructing the images from projections is called the "Inverse Radon Transform". These transforms are available in MATLAB as built-in functions "*radon*" and "*iradon*".

Generate a "phantom" image in MATLAB using the following command:

```
P = phantom('Modified Shepp-Logan',256);
```

This digital phantom presents an axial crosscut of a human body, showing the lungs, the heart, and a few blood vessels. "P" is our "ideal" image.

There are different filter options available in *"iradon"*. Type "help iradon" to see how you can use them:

(1) "Ram-Lak" filter: Default filter in "*iradon*". This is a cropped ramp filter, i.e., ramp filter multiplied with a rectangle window.
(2) "Hamming" filter: Ramp filter multiplied with a smoother window called Hamming window.
(3) "none": No filter, corresponding to direct backprojection reconstruction without any filtering.

a) Display the phantom P.

b) Using Radon transform, take projections of P at 180 different angles between 0^{o} and 180^{o} (i.e., theta = [0:179] when using "*radon"*). Display the sinogram. Reconstruct the image using inverse Radon transform function with "Ram-Lak", "Hamming", "none" filter options. Comment on the differences that you see in the reconstructed images.

c) Again, use theta = [0:179] to take Radon transform, i.e., R = radon(P,theta). These projections are our measurements. Now add Gaussian noise with zero mean and a standard deviation of 5 to these measurements (independent identically distributed). Display the sinogram. Reconstruct the image using inverse Radon transform function with "Ram-Lak", "Hamming", "none" filter options. Comment on the differences that you see in the reconstructed images.

d) Take Radon transform using fewer number of projections, with theta = [0:5:179]. Here, we have 36 projections, which is not sufficient to reconstruct a high quality image. As a result, there will be what is called "streaking artifacts" in the reconstructed image. Display the sinogram. Reconstruct the image using inverse Radon transform function with "Ram-Lak", "Hamming", "none" filter options. Comment on the differences that you see in the reconstructed images.