

MIC Assignment-2

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1 Question 1: X-Ray Computed Tomography – Radon Transform

A 128×128 Shepp–Logan phantom was generated and treated as the image $f(x, y)$. The coordinate origin was logically placed at the center pixel.

(a) Implementation of `myXrayIntegration()`

The function `myXrayIntegration(f, t, theta_deg, delta_s)` computes the line integral of image intensities along a line parameterized by t and θ .

Implementation details:

- The angle `theta_deg` is converted to radians.
- A sampling variable `s` is created from $-N$ to N with step size `delta_s`.
- For each value of `s`, corresponding (x, y) coordinates are computed.
- `map_coordinates()` is used to interpolate image values.
- The interpolated values are summed and multiplied by `delta_s`.

Interpolation Scheme: Bilinear interpolation (`order=1`) was used because:

- It provides smooth transitions between pixels.
- Nearest-neighbor interpolation produces jagged artifacts.
- Higher-order interpolation increases computation unnecessarily.

(b) Implementation of `myXrayCTRadonTransform()`

The function `myXrayCTRadonTransform()` computes the Radon transform over discrete values:

- `t = -90 to 90` with step size $\Delta t = 5$
- `theta = 0 to 175` with step size $\Delta \theta = 5$

For every (t, θ) pair, the function calls `myXrayIntegration()` and stores the result in a 2D array.

(c) Comparison of Different Δs Values

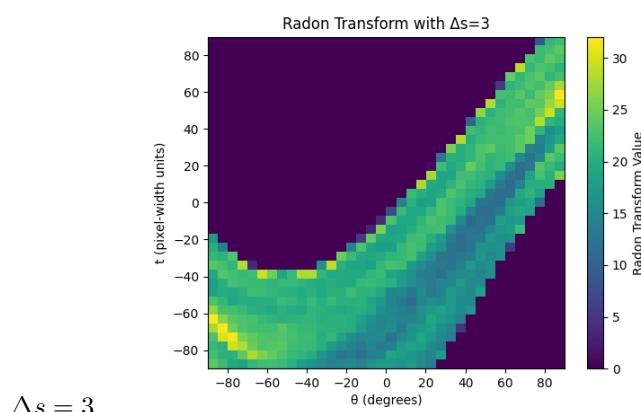
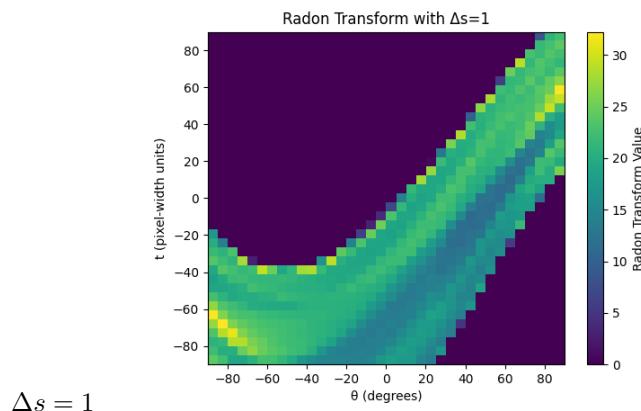
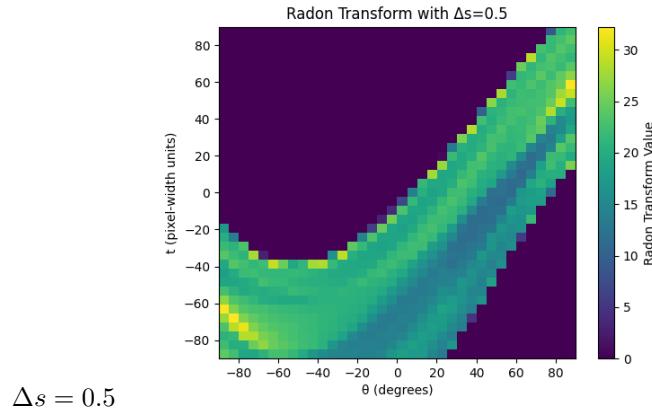
Choice of Δs : Different values were tested: 0.1, 0.5, 1, 3, 10 pixel units.

Observations:

- Very small Δs increases computation with little improvement.
- Infact $\Delta s = 0.1$ performed worse than $\Delta s = 0.5$.
- This is due to overfitting by interpolation.
- $\Delta s = 0.5$ or 1 gives stable and smooth results.
- Large Δs (3 or 10) causes rough and blocky sinograms.

Δs	Smoothness Score
0.1	0.00766441
0.5	0.00766361
1	0.00766573
3	0.00792422
10	0.01310446

Table 1: Smoothness scores for different Δs values.



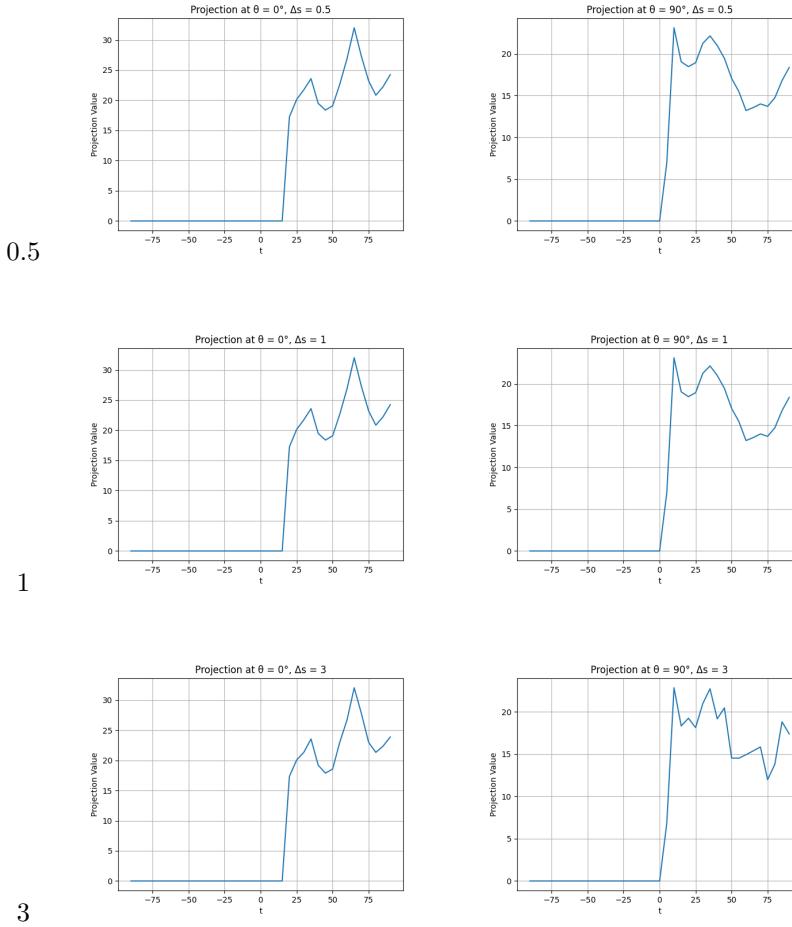
Additionally, 1D plots of the sinogram values were examined for:

1D Projection Comparisons for Different Δs

Δs

$\theta = 0^\circ$

$\theta = 90^\circ$



Observations:

- Smaller Δs produces smoother 1D curves.
- Larger Δs produces visible roughness due to coarse sampling.
- Among the tested values, $\Delta s = 0.5$ appears smoothest.

A smoothness score was computed using the function `apply_prior()`, which evaluates local intensity differences. Lower values indicate smoother sinograms.

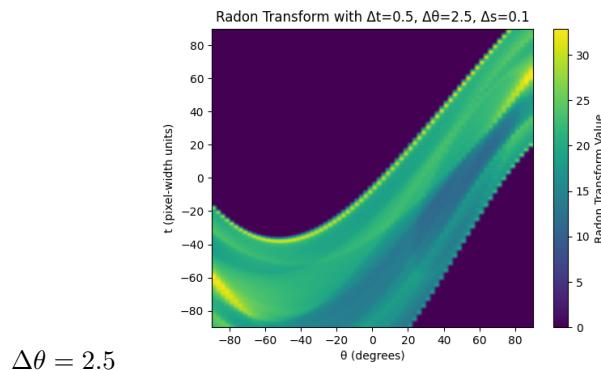
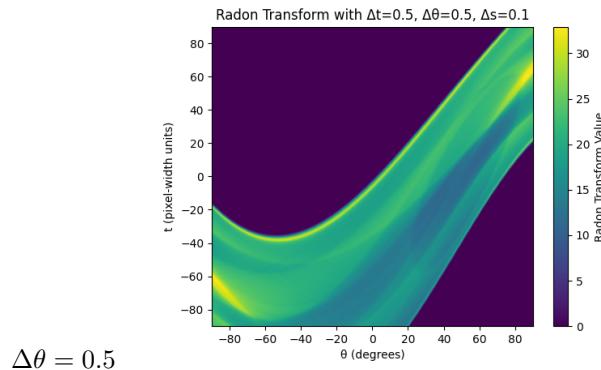
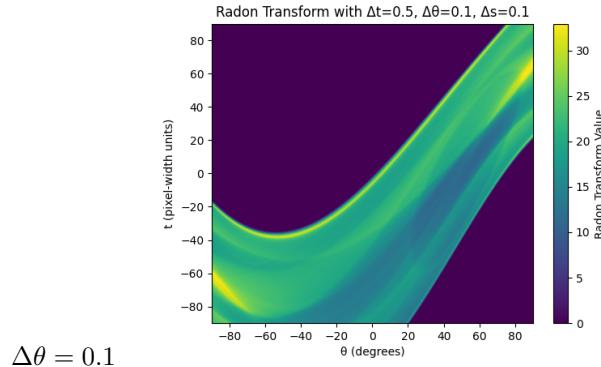
Results show:

- $\Delta s = 0.5$ gives the lowest smoothness score.
- $\Delta s = 1$ and 3 give slightly higher scores, indicating more roughness.

(d) Choice of Δt and $\Delta\theta$ in Scanner Design

$\Delta\theta$:

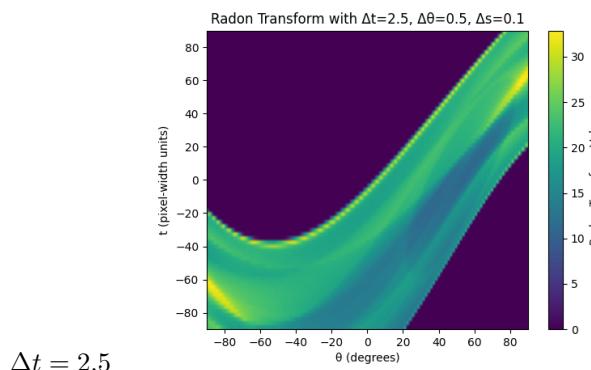
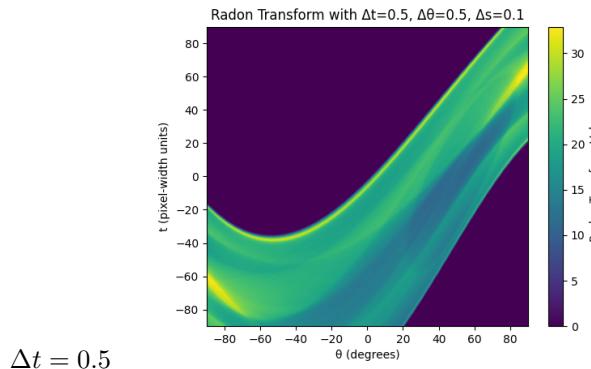
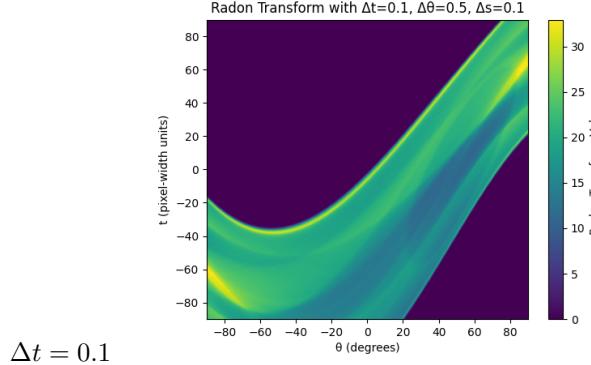
- Smaller $\Delta\theta$ improves angular resolution.
- Too small increases radiation exposure and scan time.
- A moderate small value is preferred.



Δt :

- Smaller Δt improves spatial sampling.
- Very small Δt increases noise sensitivity.

- Larger Δt introduces discretization artifacts.



Thus, both parameters must balance resolution, noise, and acquisition cost.

(e) Design Considerations for ART Reconstruction

Number of Pixels and Pixel Size:

- More pixels improve spatial resolution.
- However, computational cost increases significantly.
- Smaller pixels receive fewer photons, increasing noise variance.

A moderate grid resolution is therefore preferred.

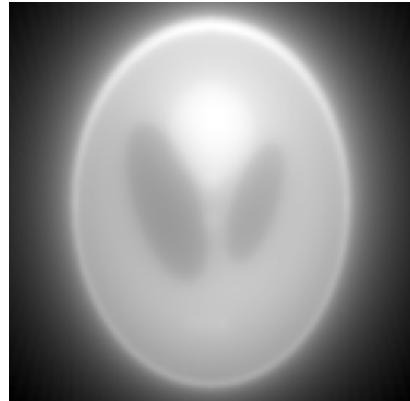
Effect of Δs :

- $\Delta s \ll 1$ pixel width:
 - More accurate integration.
 - Higher computational cost.
 - Less energy per pixel so noise has greater effect.
- $\Delta s \gg 1$ pixel width:
 - Underestimates line integrals.
 - Produces blocky reconstruction.
 - Slows ART convergence.

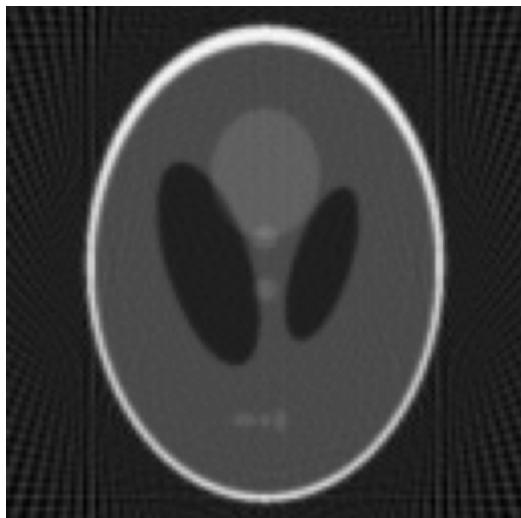
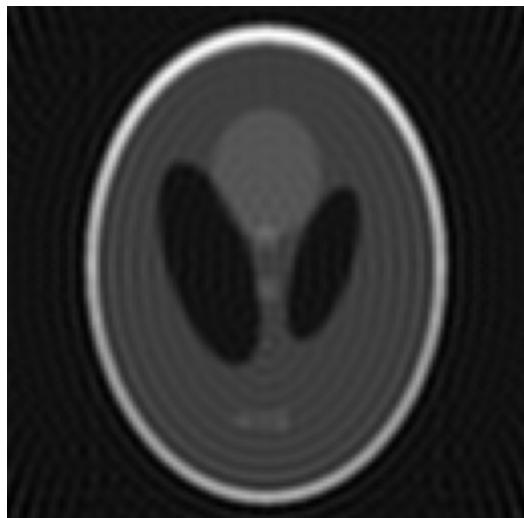
Summary

The experiments demonstrate that:

- Δs should be comparable to pixel width.
- Δt and $\Delta\theta$ should be small but not excessively small.
- There is a trade-off between resolution, noise sensitivity, radiation dose, and computational complexity.

2 Question 2

No Filtering

Ram-Lak ($L = 0.5$)Ram-Lak ($L = 0.25$)

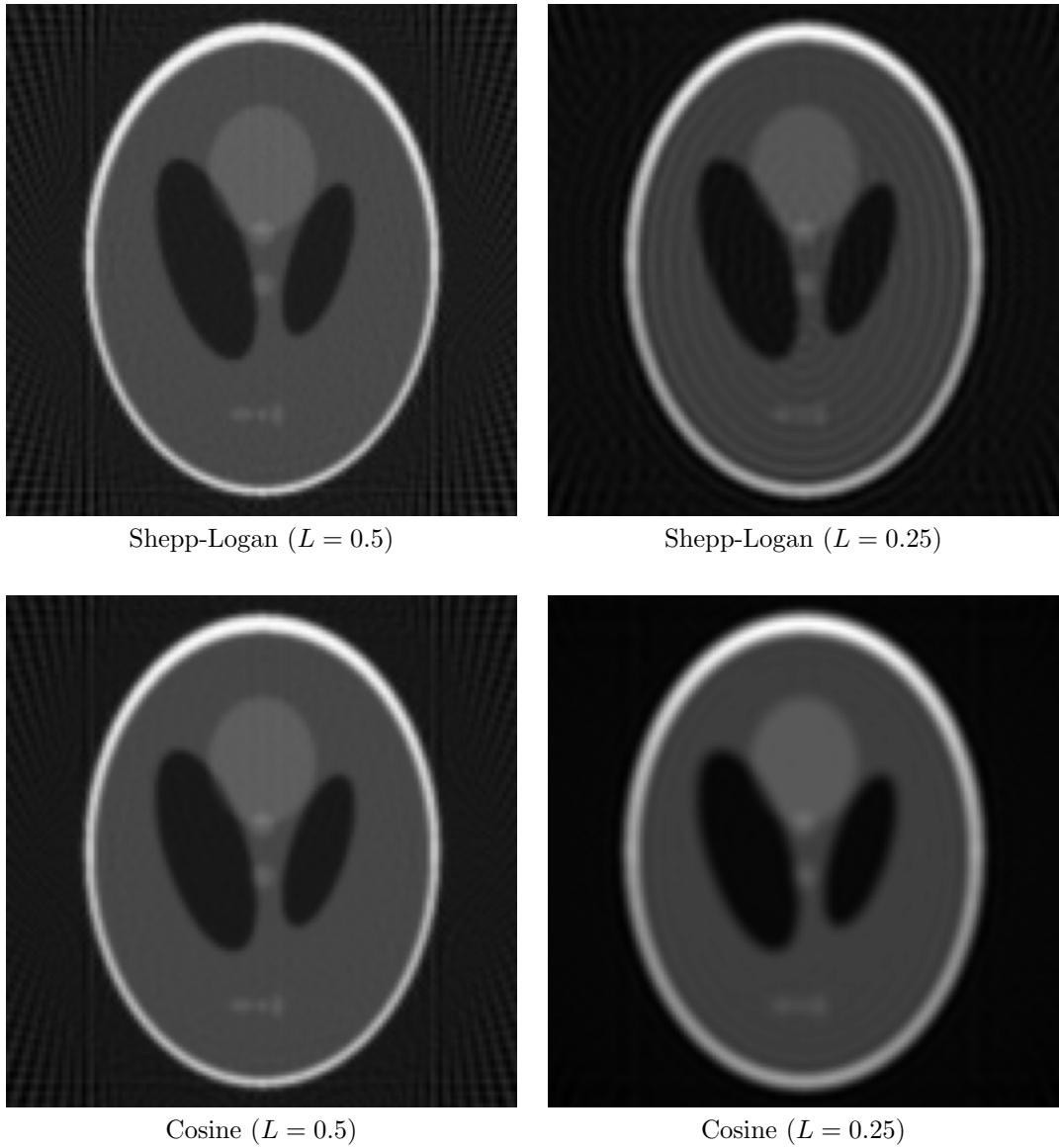


Figure 1: Comparison of reconstructed images using different filters and cutoff frequencies.

3 Question 3

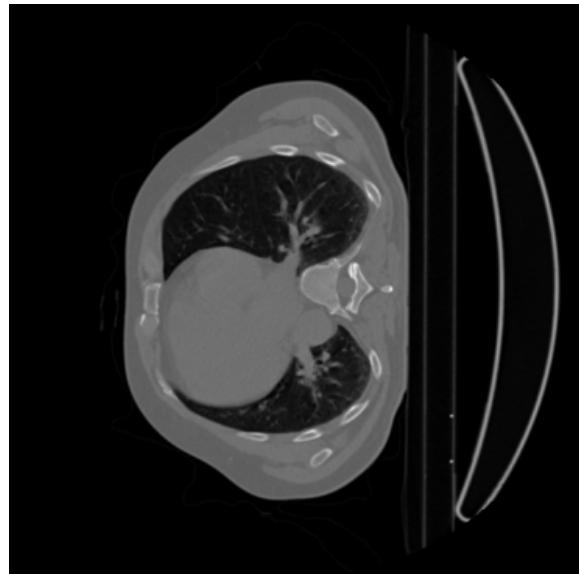


Figure 2: Original Image - Chest CT



Figure 3: Original Image - Phantom

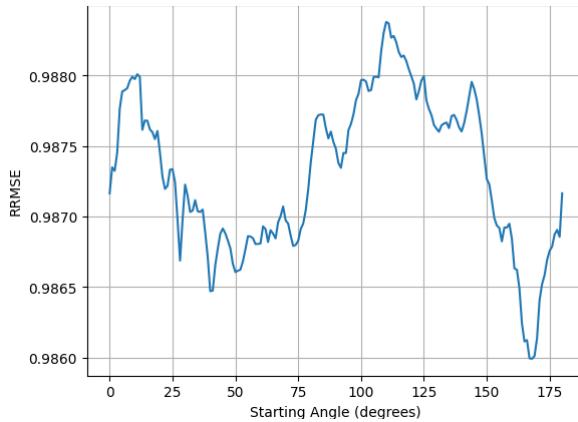


Figure 4: RRMSE Plot - Chest CT

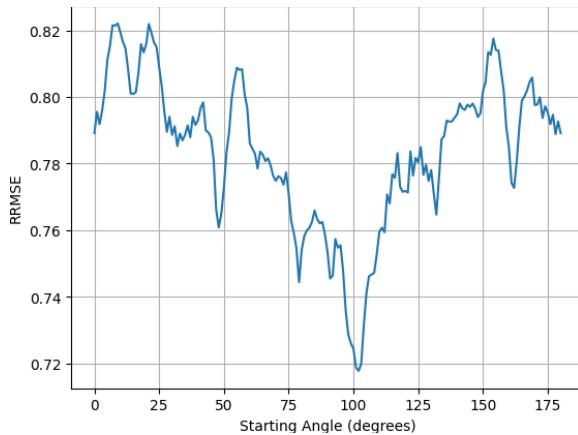


Figure 5: RRMSE Plot - Phantom

Minima of RRMSE for Chest CT is an RRMSE of 0.9859919140151212 at 168 degrees. For phantom, it is an RRMSE of 0.7176981638852817 at 102 degrees.

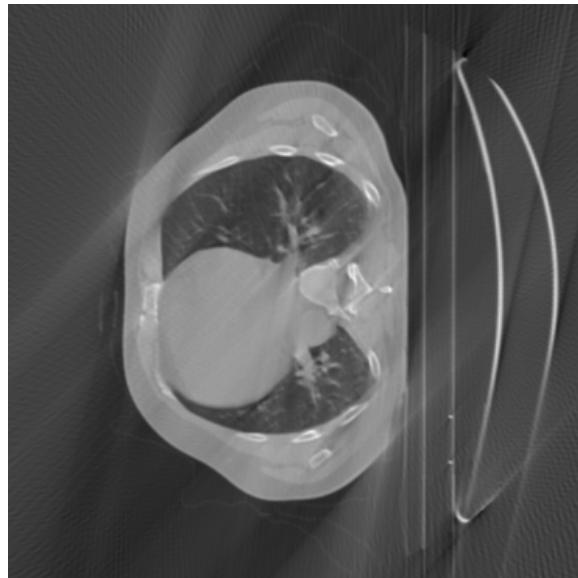


Figure 6: Optimal Reconstruction - Chest CT



Figure 7: Optimal Reconstruction - Phantom