PROJECT BME 2023

Fan-beam tomographic image reconstruction

The aim of the project is the understanding of the effect of key-parameters of Filtered Back-Projection (FBP) image reconstruction on X-ray Computed Tomography (CT) image quality. The following two effects will be analyzed:

a) the effect of different reconstruction kernels (filters) and
b) the effect of reconstruction filter cut-off frequency.

MATLAB Programming Environment
To carry out the processing steps of the project, familiarization with functions of the MATLAB programming environment (Image Processing Toolbox) provided in the Presentation entitled “CT Image Reconstruction: Project BME 2023”, is required:

The project input data correspond to 2D original CT axial slice images of a CT physical phantom (Image1-Image3), acquired at different exposure conditions (different tube voltage).

The following images must be provided:

- Read and display one (1) 2D axial slice image.
- Generate the sinogram of an axial slice image (function: fanbeam) for different combinations of profile sampling interval (Δr: sensor spacing) and angular sampling interval (Δθ: rotational spacing).
- Generate reconstructed axial slice images (function: ifanbeam) for different reconstruction filters (parameter: Filter) of different cut-off frequency (parameter: FrequencyScaling: % of maximum frequency), adopting non-linear (cubic) data interpolation in all reconstructions.

Quantitative Assessment of Image Quality in Reconstructed Images
The following quantitative image quality indices need to be calculated for the original CT axial slice image and its different reconstructed versions, for different reconstruction filters and frequency scaling conditions:

a) Calculate image background Noise (use circular ROI) at different locations.
b) Calculate Contrast to Noise Ratio (CNR) for two (2) different circular objects of your choice, corresponding to tissue equivalent materials.
c) Estimate Edge Spread (Blur) function of the two (2) above circular objects.

To carry out ROI measurements, circular ROIs (e.g. roi=images.roi.Ellipse, or imellipse) are to be placed at image background locations and inside the circular target objects. Specifically, for the latter, ROIs are to be placed at 50% of object boundary. For estimating edge spread function, image line profiles (e.g. improfile) should be placed along the horizontal or vertical axes of the object and should have adequate extent around the object edges.

In any case, please display the following:

1. One (1) original CT axial slice (Image1-Image3.dcm) and its sinogram.
2. The selected ROIs and Profile lines on the original image and the various different reconstructed versions of it, used to derive background Noise, CNR and Edge Spread (Blur).
3. The sinograms of the original image for the following specific combinations of sensor spacing (Δr: 0.8^0, 0.5^0 and 0.2^0) and rotation increment (Δθ: 3°, 2° και 1°, corresponding to 120, 180 και 360 angular sampling).
4. The reconstructed images by applying different reconstruction kernels (filter: Ram-Lak, Shepp-Logan and Hamming) with cut-off frequency values (frequency scaling: 100%, 90% and 80%), assuming a theoretically optimal Δr and Δθ combination.

Questions

1. Selecting the optimal profile sampling and angular sampling conditions (Δr, Δθ) among the ones tested, by visual inspection, how is image background noise, CNR and edge blur differentiated with respect to each image reconstruction filter and filter cut-off frequency? Please provide the corresponding graphs to justify your answer.
2. What is the optimal filter and frequency scaling combination for optimal detectability of the two (2) target materials of your choice?