Title: Virtual CT Scanner

OVERVIEW: Implement a virtual CT scanner and study the effect of changing imaging parameters on the image quality. Implement the software to simulate your scanner on Matlab and use a GUI to run it. Through this GUI you should be able to change the characteristics of your phantom, the parameters to control data acquisition, view the reconstructed images and perform simple analysis. The majority of your work will be performed on “test/validation” phantoms. Those will be simple phantoms like those two in the figure below: a circular one with circular and rectangular structures. You will use those phantoms to study and analyze the effect of different acquisition parameters on image quality. The second phantom will be a head phantom generated with the phantom() function of Matlab. Use this as a final demonstration that your scanner works properly!

SPECIFICS:
1. Develop the different functions/code to perform all necessary calculations for:
   - Generate the phantoms
   - operation of the scanner
   - image reconstruction
   - image analysis
2. Implement a GUI that combines those pieces of code and performs the different tasks.
3. Test/validation phantom: a cylinder one with several circular structures of different sizes and the other with a single rectangular structure in the middle (see figures above). From your GUI you should be able to change the matrix size, the dimensions and __ values of the structures.
   Note: Assign to each structure __ values different enough so you can have good contrast differences; after you have your GUI ready just test different combinations.
4. Head-phantom: Use the phantom() function by Matlab.

5. Image Analysis: Implement code for three types of image analysis:
   - Signal Intensity (SI) and Contrast (relative signal intensity differences between two regions). These quantities should be reported as numbers and you will use them to investigate whether your calculations are correct (how? e.g. is the beam attenuation correctly calculated?)
   - Image Difference: This will be used to compare your image generated by your scanner and the original input which is your phantom. You will use this type of analysis to identify artifacts or other problems with image reconstruction.
   - Signal Intensity (SI) profiles: Generate graphs of the signal intensity vs. position along a specific direction. You will use those graphs to investigate for potential artifacts. You must be able to compare the profile of both your original object (phantom) and your image (the output of your virtual scanner). So, you can arrange to view two or more profiles in the same figure-graph.

6. The scanner part of the GUI should allow you to change the different parameters of data acquisition: number of detectors, distance or density of detectors, type of detector array (linear or arc), the distance of the source from the center of the scanner, the step angle of the detector as it goes around the patient. Add a run button to activate the acquisition. In the output do not forget to add appropriate comments that list the parameters you used (Matlab gives you some good options for this)

7. Using the test/validation phantom investigate the effect of changing acquisition parameters. In all cases the “ground truth” is your original phantom! You will compare the images generated by your code relative to this phantom! You will use the different tools in section 5 to investigate how your scanner works. Compare the image and the validation phantom for different acquisition parameters:
   - What is the effect of increasing the step of the rotation angle?
   - What is the effect of reducing the number or the distance of the detectors?
   - In the phantom with the circular structures, what is the effect on them?
   - How are the edges of the rectangular structure in the second phantom appear in the image? Any improvements?
   - What is the overall image impression? What may cause this phenomenon?
   - What parameters give you the best possible image?
   - Add a time parameter and (e.g. the duration of data acquisition per rotation) and investigate how “the longer the acquisition time the better the collected images”