**PHYS 540 Assignment 2: CT**

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**1. (/5) Discuss the advantages and disadvantages of 3rd generation CT scanners over 4th generation CT scanners.**

The design of 3rd generation CT scanners (rotate-rotate) involved the X-ray tube and curved detector array (arranged in an arc) rotating together around the patient, with fan beam geometry. 4th generation scanners (rotate-stationary) had a rotating X-ray tube with a stationary detector ring (360 degree array of detectors), this design also used fan beam geometry.

Advantages of 3rd generation scanners over 4th include lower cost, since less detector elements are needed. This design is also less complex with the only active detector elements being directly opposite to the X-ray source. Stationary rings in 4th generation scanners would collect more scatter from the patient, resulting in more detector crosstalk.

Disadvantages of the 3rd generation scanners over 4th generation include that ring artifacts can be produced from improperly calibrated detector elements in the reconstructed image. This is a disadvantage to having rotating detector elements. Additionally, 4th generation scanners would have less mechanical stress from the detector array. The rotation from the 3rd generation scanners would mean a heavier gantry with more mechanical wear and vibrations.

**2. (/5) Discuss the tradeoffs that occur when decreasing voxel size in CT imaging.**

A pixel in a CT image corresponds to volume elements (voxels) in the patient’s body. Decreasing the voxel size would mean that each voxel represents a smaller volume of tissue, which would capture fine anatomical details more accurately (improved sampling). This means that the spatial resolution would improve. This comes with some negative effects including higher image noise, increased detector cross talk, longer reconstruction time, and higher computational load.

In order to maintain the same SNR with smaller voxels, the more photons must be used (increased mAs), this increased the dose. Additionally, smaller detector elements closer together could result in increased crosstalk and electronic noise, as there could be more light spread between elements. Smaller voxels would also generate more data to reconstruct; this would result in longer processing time and a higher computational load/ storage requirement.

**3. (/5) Describe beam hardening in CT imaging. Explain the effects of beam hardening on CT images. Can beam hardening artefacts be removed or compensated for?**

Beam hardening relates to the increase in effective energy of the CT X-ray beam as the poly-energetic beam passes through increasing thickness of tissue. We know that the many lower energy components of the spectrum will be attenuated, and this will cause the effective energy of the spectrum to increase. Higher attenuating materials such as bone will cause more dramatic beam hardening as opposed to soft tissue.

In CT imaging, the effects of beam hardening can be seen more dramatically than in other imaging modalities because of back projection. For example, for a voxel that is reconstructed in a region of soft tissue, some rays detected may have passed through higher attenuating materials and may have had more beam hardening than other rays back projected through that voxel. This can lead to beam hardening artifacts which manifest as low density (dark) streaks that run between high density regions (light).

In order to compensate for beam hardening in CT, the x-ray beam is filtered by relatively thick sheets of metal (eg. 10 mm of Al). This ‘pre-hardens’ the beams to reduce beam hardening artifacts.

**4. (/15) In this problem you are to perform a simple and filtered reconstruction on a test object. Use a computer (as opposed to hand-calculations). You can use either a mathematical package (e.g. Matlab) or write your own code (e.g. in C).**

To begin, construct a simple test pattern consisting a non-attenuatig medium with an attenuating block in its centre. Construct the medium to be a square matrix, 21×21 pixels in size. Give this medium a linear attenuation coefficient µ = 0 mm−1 . The central 3×3 pixel area is attenuating, set the attenuation coefficient of this region to be µ = 5 mm−1. Each pixel should be 1×1 mm.

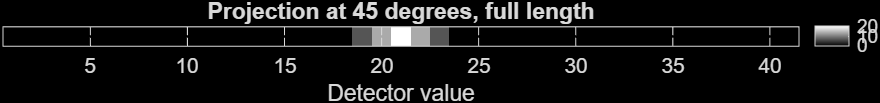
1. (/2) Consider 3 views: 0◦ (top → bottom), 45◦ (diagonal), and 90◦ (left → right). Calcu late the projection for each view. Plot each projection. The combination of the project tions is a sinogram.

A black and white rectangular object with white text

AI-generated content may be incorrect.

A close-up of a measuring device

AI-generated content may be incorrect.



A graph of a number of degrees

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1. (/5) Use the 3 views from part (a) to calculate a simple backprojection. Plot a grayscale image of the simple backprojection.

A graph of a cross with a line

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1. (/5) Using the same views as in part (a), calculate a filtered backprojection. For a filter use: y =ρo(2sinc(2ρoR) −sinc2(ρoR)) where ρo = 0.7 is a constant and R is the radial distance from the centre of the image, R=−3,−2,−1,0,1,2,3. Using this discrete dataset, y →−0.1074,0.1368,−0.3398,0.6000,−0.3398,0.1368,−0.1074 Plot a grayscale image of the filtered backprojection.

A graph of a grid

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1. (/3) Demonstrate that the second image (filtered backprojection) is an improvement over the first (simple backprojection) by calculating a rough 1/r blurring for both images. To do this, calculate the average pixel value for rings of varying radius centred on the image. Each ring is taken to be 1 pixel wide

A black square with a white center

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A graph with blue and orange lines

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