Engineering Tripos Part IIA
GG2: CT reconstruction and visualisation
Simulator demonstration

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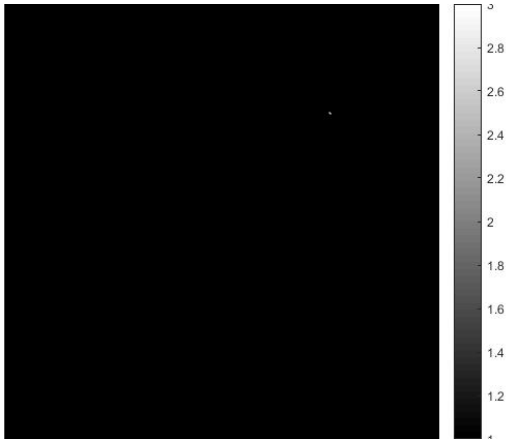
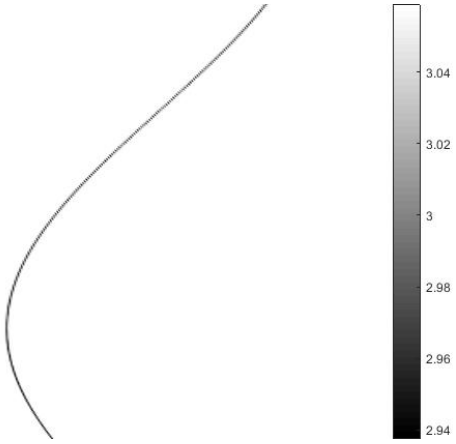
1 Sinogram

A simple test to check that the sinogram code is correct is to verify that setting the phantom image to a single test point in an arbitrary location results in a sinogram that contains a single sine wave (with a phase shift). This was indeed the case; the images are shown in Figure 1.



(a) Phantom image (test point in centre of first quadrant)



(b) Sinogram

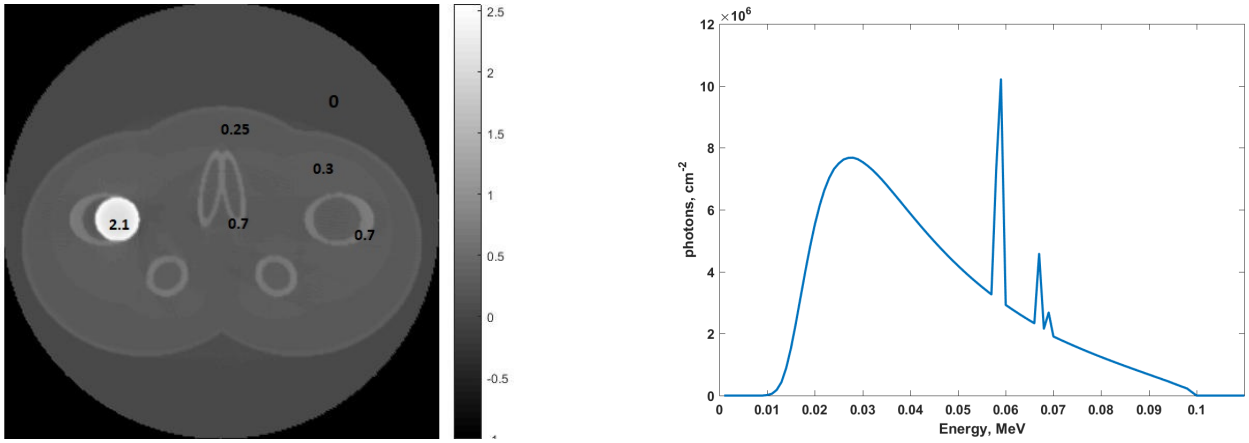
Figure 1: Phantom and sinogram for single test point

2 Final Reconstruction

We can verify that the final reconstruction looks reasonably correct because the attenuation coefficients in the reconstructed image correspond to the attenuation coefficients exhibited by

the materials being scanned. For this and the rest of the report we have used the hip replacement scan as it contains a variety of materials and is fairly complex (making it more likely that we would spot something going wrong).

The source energy range diagram shown in Figure 2b indicates that most photons from the source have an energy between 0.04 MeV and 0.08 MeV. The attenuation coefficients for the simulation, which were obtained from the reconstructed hip replacement image shown in Figure 2a are displayed in Table 1 along with the expected attenuation coefficients between 0.04 MeV and 0.08 MeV for each material in the hip cross-section image. The expected coefficients were obtained from the 'mass_attenuation_coeffs.xls' reference document. Table 1 confirms that the simulated results closely resemble our expected results. Titanium has a large range of attenuation coefficients within the small energy range whilst Adipose and Soft Tissue have smaller ranges that overlap significantly. The observed attenuation for soft tissue lay slightly outside the expected range, but this could be due to the low precision of the colour chart from which the results were derived.



(a) Reconstructed hip replacement image

(b) Energy range of X-ray source

Figure 2: Reconstructed hip replacement and range of X-ray source used in scan

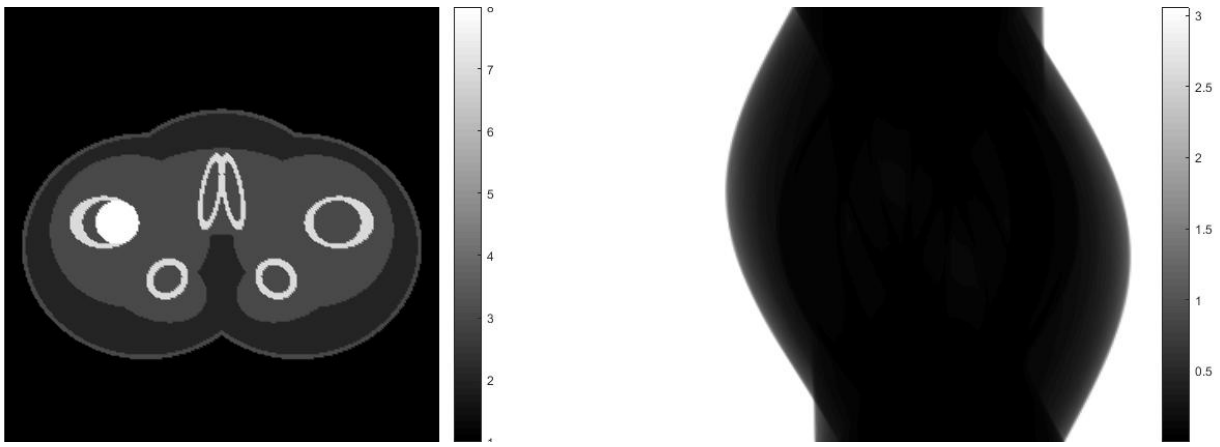
Material	Attenuation in simulator (cm^{-1})	Expected attenuation range (cm^{-1})
Titanium	2.1	1.84 to 10.05
Bone	0.7	0.43 to 1.28
Adipose	0.25	0.17 to 0.29
Soft Tissue	0.3	0.19 to 0.28

Table 1: Table of expected and simulated attenuation coefficients

3 Reconstruction Pipeline

It is also possible to verify each step in the reconstruction is correct by checking that the image it outputs corresponds to our knowledge of the reconstruction process.

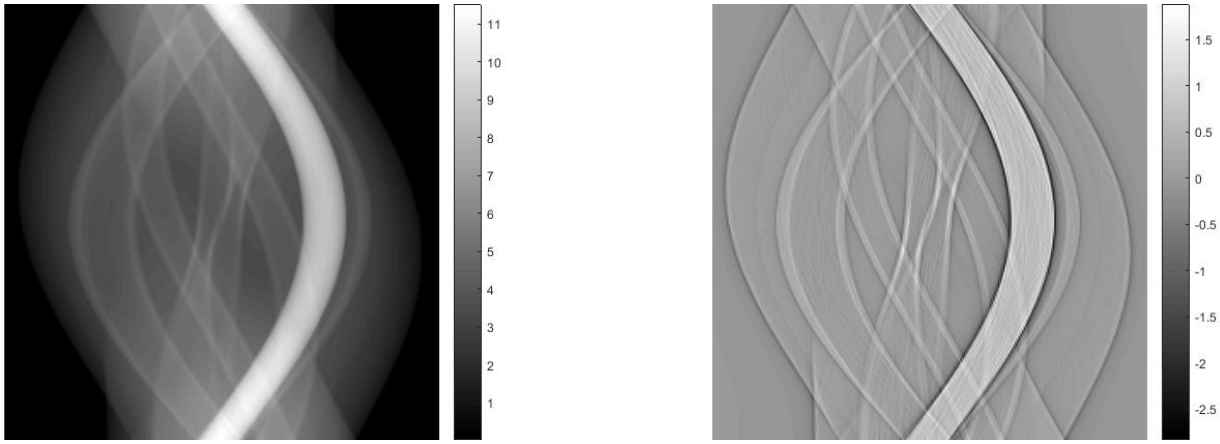
The phantom image used is shown in Figure 3a for reference. The unprocessed sinogram is shown in Figure 3b. As expected, the outlines of the silhouette appear like a sine wave. Fur-



(a) Phantom image **(b)** Sinogram (uncalibrated, unfiltered)

Figure 3: Phantom and initial sinogram for hip replacement

ther sine wave-like features can be seen after calibration (Figure 4a), where a reference scan of air is used to scale the sinogram from intensity readings to total attenuations. A Ram-Lak filter is then applied to generate Figure 4b; edges appear enhanced as high spatial frequency components are multiplied by greater filter coefficients.



(a) Sinogram (calibrated, unfiltered) **(b)** Sinogram (calibrated, filtered)

Figure 4: Processed sinograms for hip replacement

A final check is to compare the reconstructed image (Figure 2a) with the phantom (Figure 3a). The geometric features are almost identical. The pixel intensities are somewhat different, which is to be expected, as the former's pixel values are dictated by a value assigned to each material, whilst the latter's pixel values are defined by the estimated attenuation coefficients. The reconstructed image exhibits an artifact known as cupping: the attenuation of the adipose tissue appears to get lower towards the centre of the reconstructed image.