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Lecturer:	Dr. Colin Flanagan
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Introduction

It is possible to reconstruct an image, to varying degrees of quality, given the parallel-projection sinograms of the image. This technique forms the basis for many different applications, mainly in medical imaging. Tomography, coming from the Greek *tomos*, “slice/section” and *grapho*, “to write”, is a method of reconstruction from ‘slices’ through an object, e.g a brain or abdomen cross section, by some penetrating wave such as X-rays or ultrasound. Myriad types of modern tomography applications exist. One of the most common in use is the CT/CAT (Computer assisted tomography) scan, using X-ray as a basis. Some other examples include PET scan, which uses positron emission and SPECT which uses Gamma ray to scan slices.

Aims

The aim of this project is to reconstruct an image from the given parallel-projection sinogram using Python. The sinogram used is shown in Figure 1. This is composed of the projections for all X-ray angles from 0-180^0 across the given cross-section.

The reconstructed image will then be compared with images reconstructed using a ramp filter and a Hamming-windowed ramp filter.

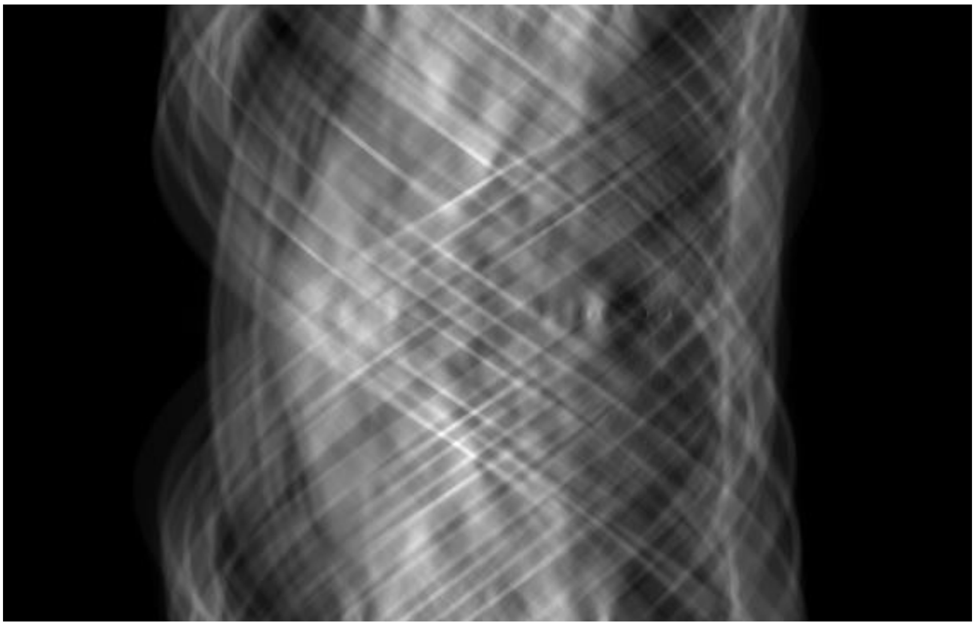

Figure 1 Sinogram to be used for backprojection reconstruction

Reconstruction without Ramp-Filtering

In order to reconstruct the original image from the given sinogram, an inverse radon transform must be completed, also known as a laminogram. The image is reconstructed by first rotating each radon projection by an angle and then summing it with the accumulating laminogram.

Figure 2 shows the image reconstructed in this manner, without any filtering or window-ing applied.

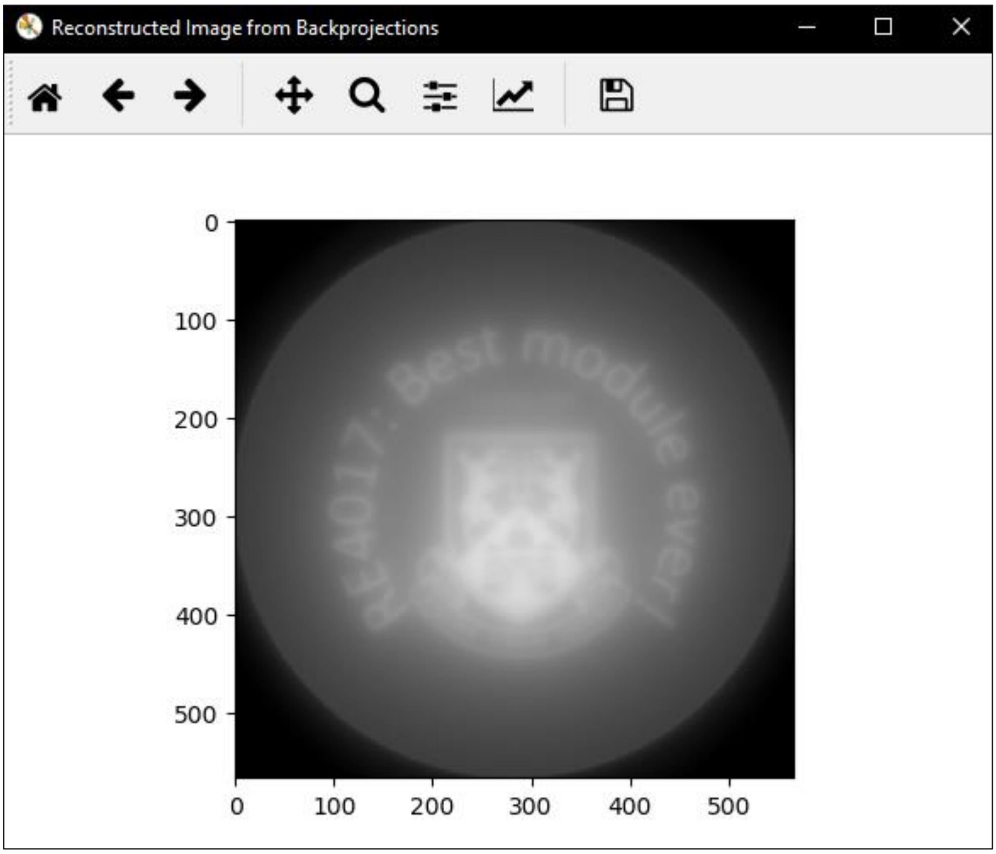

Figure 2 Reconstructed Image from Backprojections

This image (laminogram) is recovered by carrying out the following steps:

- An array of zeros is initialised, with the same dimensions as the sinogram
- The rotation constant is found to be 0.5^0 i.e `180/sinogram.shape[0]`
- The tile( ) function is used on each image bin for each rotation of the image until the sinogram has been fully rotated

As can be seen from Figure 2, the backprojected reconstruction shows a very blurred image of the UL crest with some text around it. The circle artifact around the image is also very noticeable. This can be reduced, as is demonstrated in later sections, by using filters and windows on the backprojections.

Reconstruction with Ramp-Filter

In order to improve the image recovered in the previous section, a ramp filter can be applied to the discrete fast Fourier transform of the sinogram.

Figure 3 shows the ramp filter constructed for this project. When applied to the discrete Fourier transform it curtails the components at lower array indices.

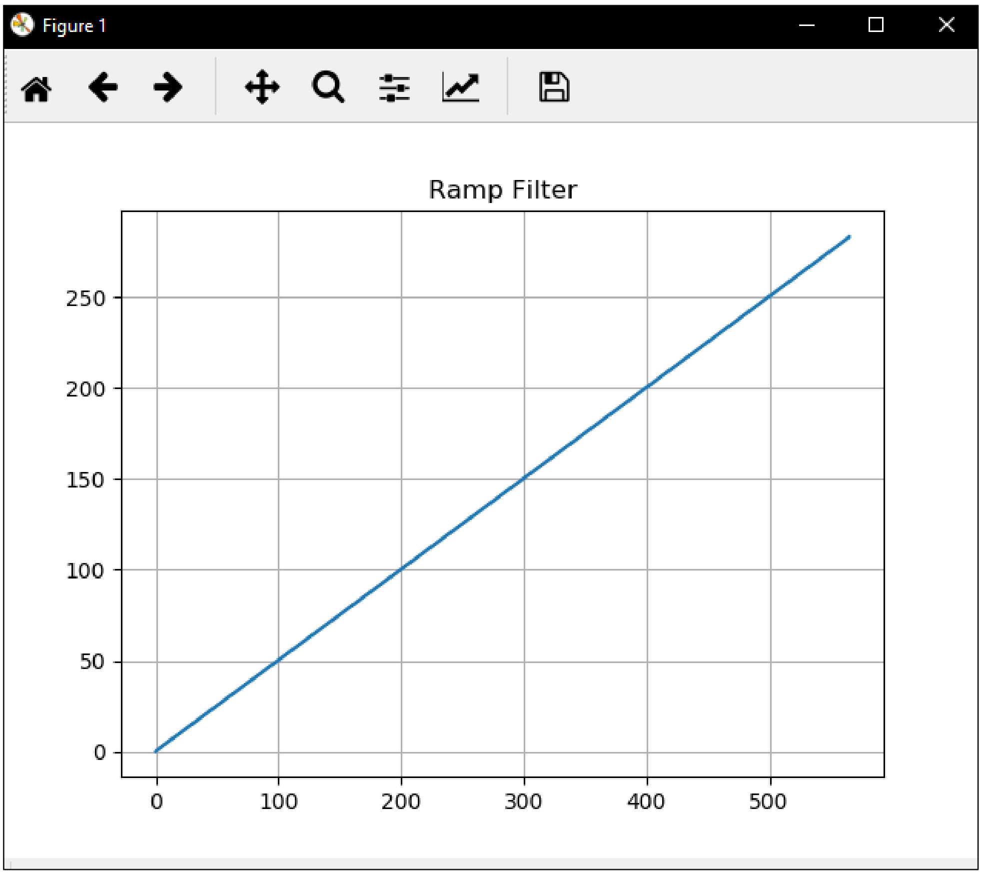

Figure 3 Ramp Filter used on FFT

Once the preceding ramp filter has been applied to the FFT projections, they can be converted back using the inverse FFT function from the scipy package, `fft.irfft( )` The resulting image is shown in Figure 4.

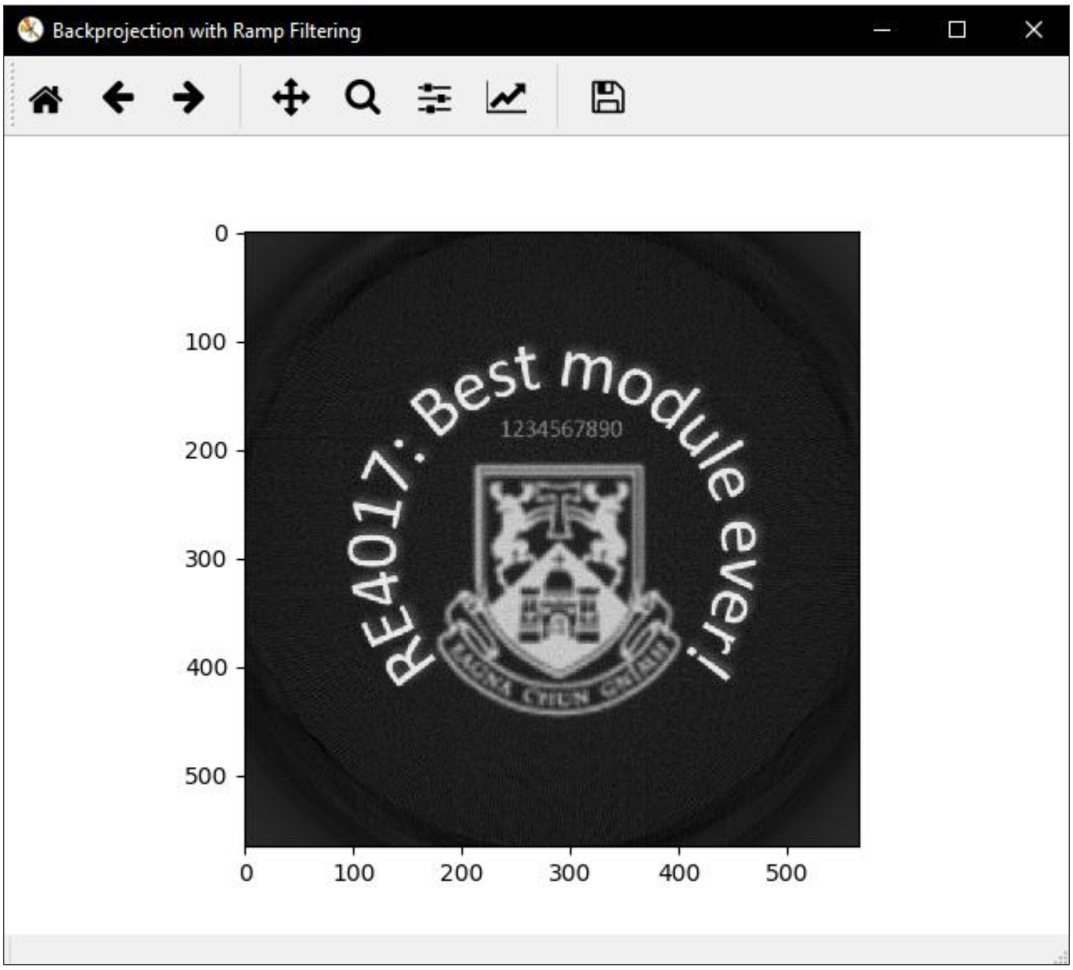

Figure 4 Ramp filtered reconstruction from sinogram

As can be seen in Figure 4, the sharpness and contrast of the image has improved greatly. The crest, lettering and numbers are now clearly visible with very defined edges. The texture of the background of the image has now also come into focus. One point to note is that the circle artifact around the outside of the image is still very visible, however the overall quality is vastly improved.

Reconstruction with Hamming-windowed Ramp Filter

In order to improve the quality of the image even further, a Hamming window can be applied to the reconstructed image. An example of a Hamming window can be seen in Figure 5. It is quite similar in shape to a Gaussian filter.

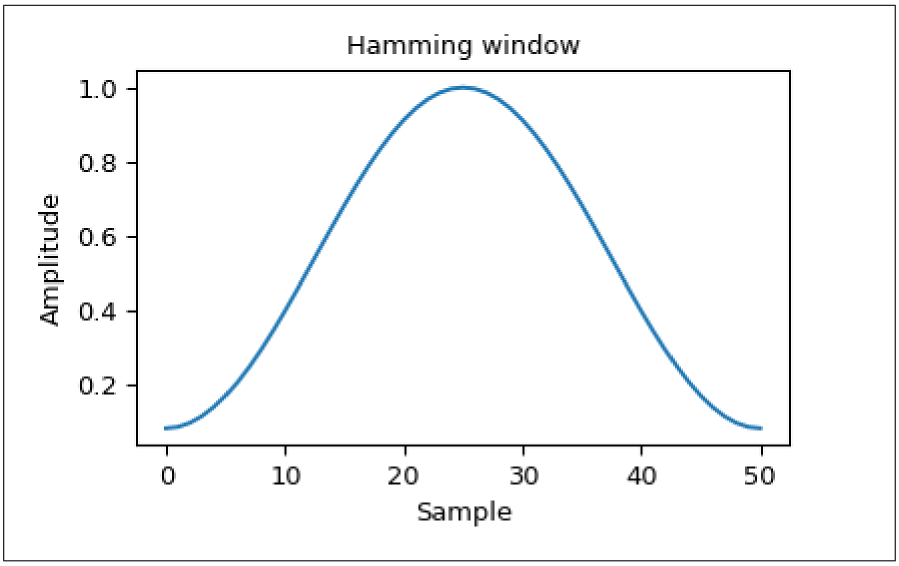

Figure 5 Hamming window
Source: https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.hamming.html

Figure 6 shows the resulting image once the Hamming window has been applied. The sharpness and quality of the image derived in the last section remains intact, however the circle artifact around the edges of the image has been smoothed and reduced out.

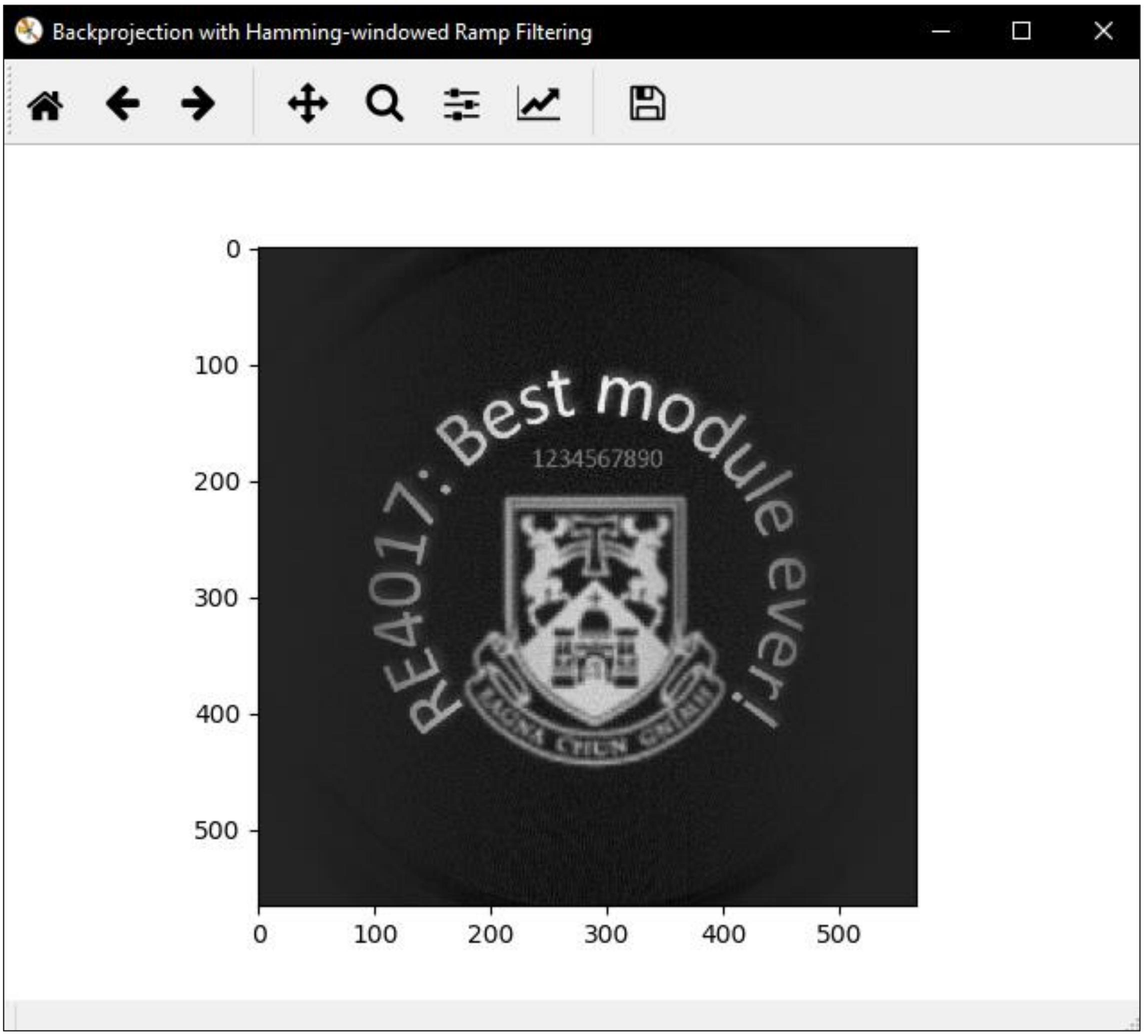

Figure 6 Hamming windowed Reconstruction

Conclusion

The original image was successfully reconstructed from backprojections of the sinogram. Once the ramp filter and Hamming window were applied to the Fourier transform of the reconstruction, it brought the image into much sharper focus.

While the claim that RE4017 is the best module ever is debatable, it is clear to see the applications of these image processing techniques especially in medical image processing such as X-rays and CT scans.