# Exercise 1: CT Reconstruction

### Overview

* In this assignment you will explore the basic principles of image reconstruction in computed tomography (CT)
* filtered back projection and iterative reconstruction.
* You will use functions to convert an image into radon space and create a sinogram, a synthetic projection per radon or fanbeam (corresponding to parallel or fanbeam geometry respectively).
* Then utilizing those synthetic projections, you will reconstruct the original image.

### What to hand in for this assignment:

Submit your notebook solutions (code)+ written explanations/ descriptions in word/pdf.

### References

<https://www.youtube.com/watch?v=rKh_XIpsuc4> : General   
<https://www.youtube.com/watch?v=q7Rt_OY_7tU>: Sinogram

<https://www.youtube.com/watch?v=MA2y_2YySq0&t=3s>: Radon Transform  
<https://www.youtube.com/watch?v=pZ7JlXagT0w> : FBP  
<https://www.youtube.com/watch?v=r5ZIzog2JlE>

<https://www.youtube.com/watch?v=gu0lcxdFO1Q>: Algebraic reconstruction

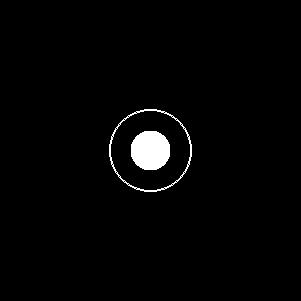
<https://www.youtube.com/watch?v=moWou9zNl1w>: SIRT

<https://www.youtube.com/watch?v=YIvTpW3IevI>: Fourier Slice Theorem

### Steps :

**Step 1:**

* Create a head phantom or use the Shepp-Logan head phantom.
* The bright ellipse corresponds to the skull and the structures inside correspond to the various brain tissues and lesions.
* Calculate the synthetic projection using radon transform (parallel beam geometry) for the head phantom and the geometric images and explain your results.



**Step 2:**

* Vary the number of projection angles (18,24, 90, ) and perform a reconstruction for each angle increment.
* Explain the effect of varying the angles.

**Step 3:**

* Demonstrate the difference of performing back projection and filtered back projection.

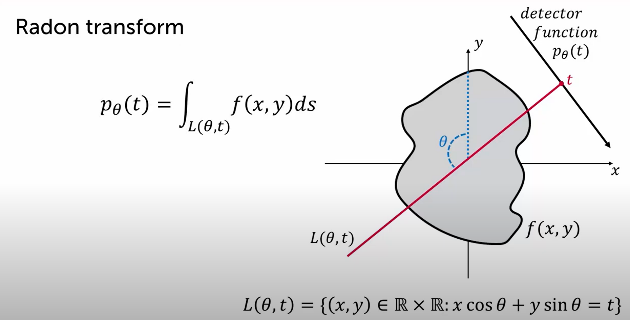
**Step 4:**

* Apply & describe an algebraic iterative reconstruction technique such as SIRT/ CGLS/ another.

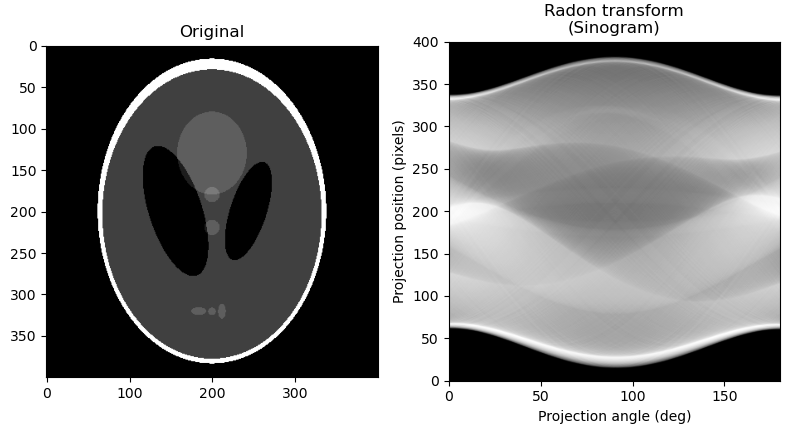
**Good luck on Exercise 1!**

**Step1:**

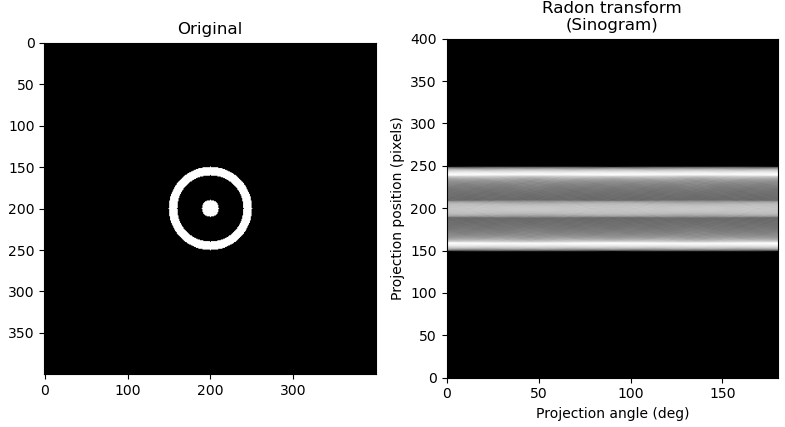
* **Radon transform background:**
  + Radon transform of an image represented by the function can be defined as a series of line integrals through at different offsets from the origin.
  + The acquisition of data in medical imaging techniques such as MRI, CT and PET scanners involve radon transform, projecting a beam through an object.
  + For any non-homogeneous shape, Sinogram created by taking the radon transform at intervals of one degree from 0 to 180 degrees.
  + Each column in sinogram reconstructed image, is a projection for each degree between 0 to 180, depend on the degree interval.



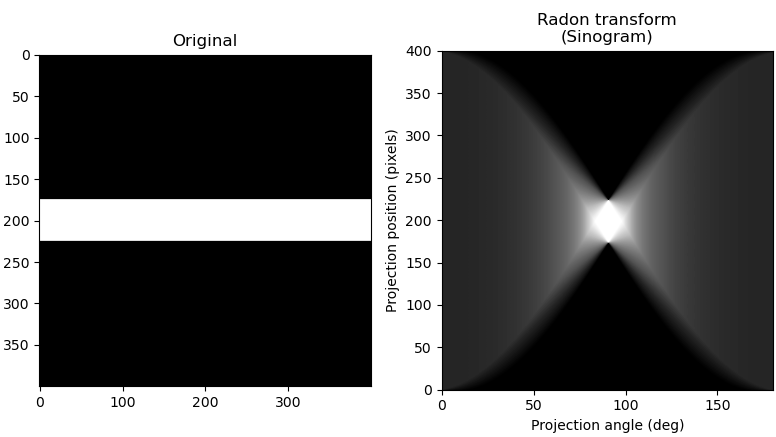
* + The reconstruction of object is dependent on the quality of sinogram, however all ray pass into the center of the non-homogeneous shape, therefore the center pixels will blur, to handle this phenomenon, it common practice to use a high pass filter is applied to the sinogram data in the frequency domain.
* **Sinogram generation:**
  + We load sinogram image in size (400,400)
  + We choose to divide the degree range into 400 degrees, in order the sinogram will be in the same image size.
  + We run radon transformation on Shepp-Logan head phantom, and 2 geometric shapes:
    - Shepp-Logan head phantom



* + - Geometric shape #1



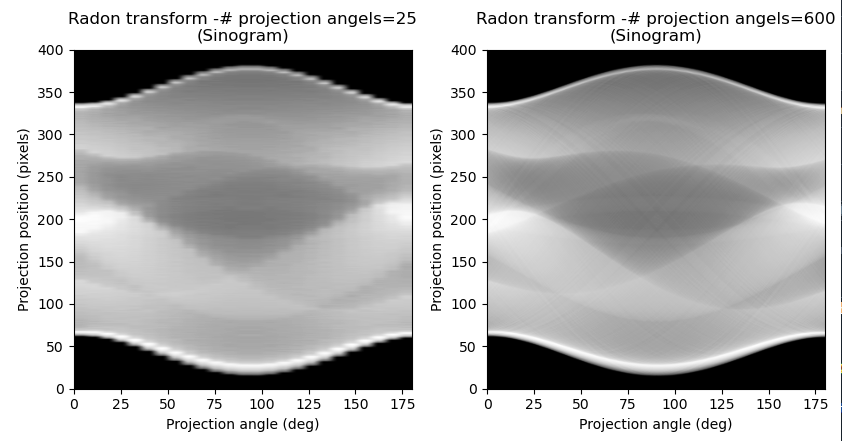
* + - Geometric shape #2



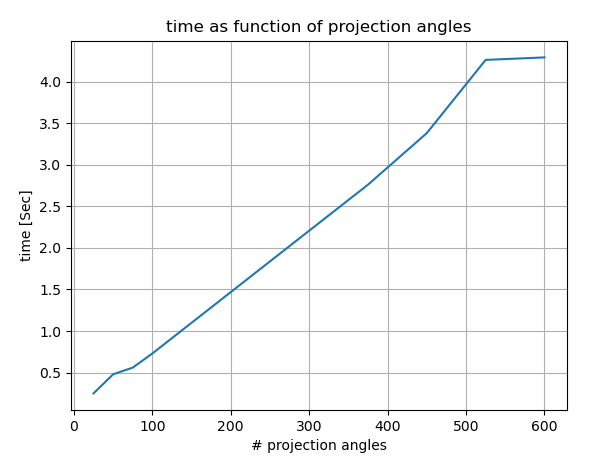
* + Main difference between sinogram of Shepp-Logan V.S 2 geometric shapes:
    - Shepp-Logan head phantom is non symmetric, and compared to the geometric shapes, the sinogram is also not have symmetric mechanism.
    - Shepp-Logan head phantom is un-uniform in pixel value, and therefore the sinogram has more variation in pixel values.

**Step2:**

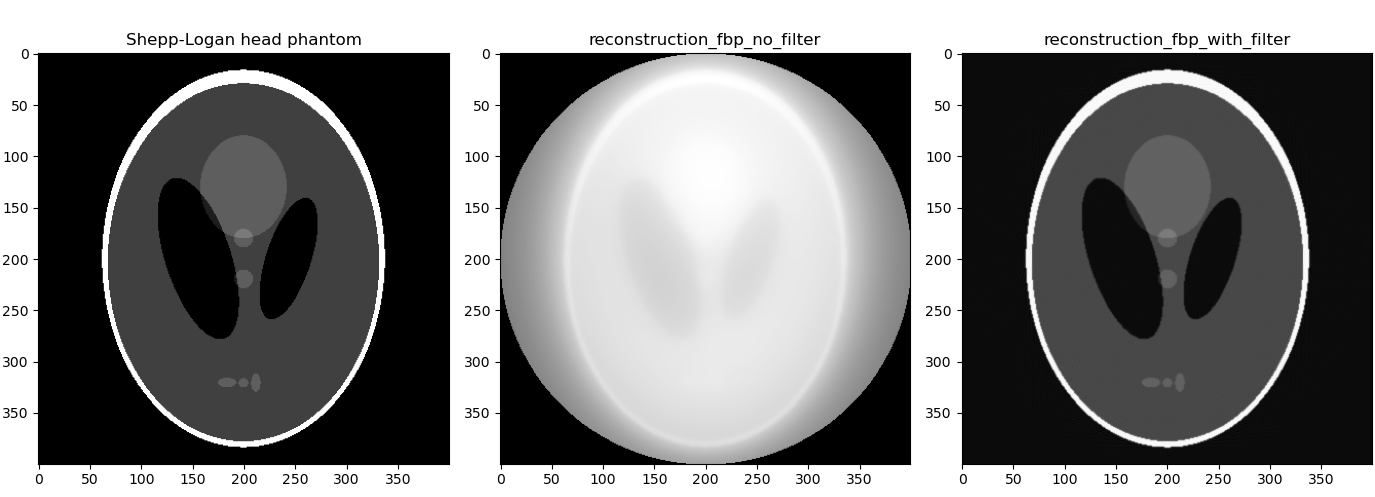
* We test different number of projection angels, as we thought as number of projection angles decrease the sinogram image is less sharp, and more blurred.
* As we increase the amount of projection angles, the sinogram image it sharper, and smoother.
* Farther more the number of angles, define the number of columns, and the random transformation is slower.
* The extreme projection angle we have chosen, it can by be seen the significant blurred in the left image, compare to right image



* the number of projection angle can be compared to sample size in signal processing, for this cause, if we sample a signal in bad frequency, we can lose vital information that will help as to reconstruct the signal, for the same reason, if we will not increase enough the amount of projection angle, the sinogram will be blurred, and will decrease our ability to reconstruct the image.
* We measure the time as function number of projection angle, and as expected there is linear connection between them.



**Step3:**

* In this part, we reconstruct Shepp-Logan head phantom from the sinogram using back projection.
* To emphasize the need for using low pass filter, we reconstruct in 2 ways:
  + Without low pass filter
  + With low pass filter
* From the image above without lowpass filter, the reconstructed image is saturated, compare to the original image, and to the reconstructed image using lowpass filter.
* To visuality the error with\without low pass filter we plot the Absolut error between the original image to the reconstructed image:
  + The MSE error is much larger in the no low pass filter case
  + In the low pass filter image, there is no match error, except from the edges of the shape, and it stand with the MSE result.

