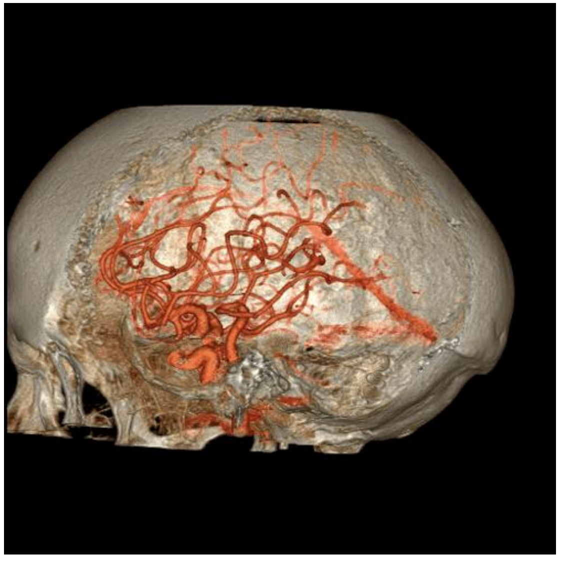
GE’s “Revolution CT”



MATLAB III: CT

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https://www.zmescience.com/medicine/inside-human-body-real-time-gifs-demo-power-ct-scan/

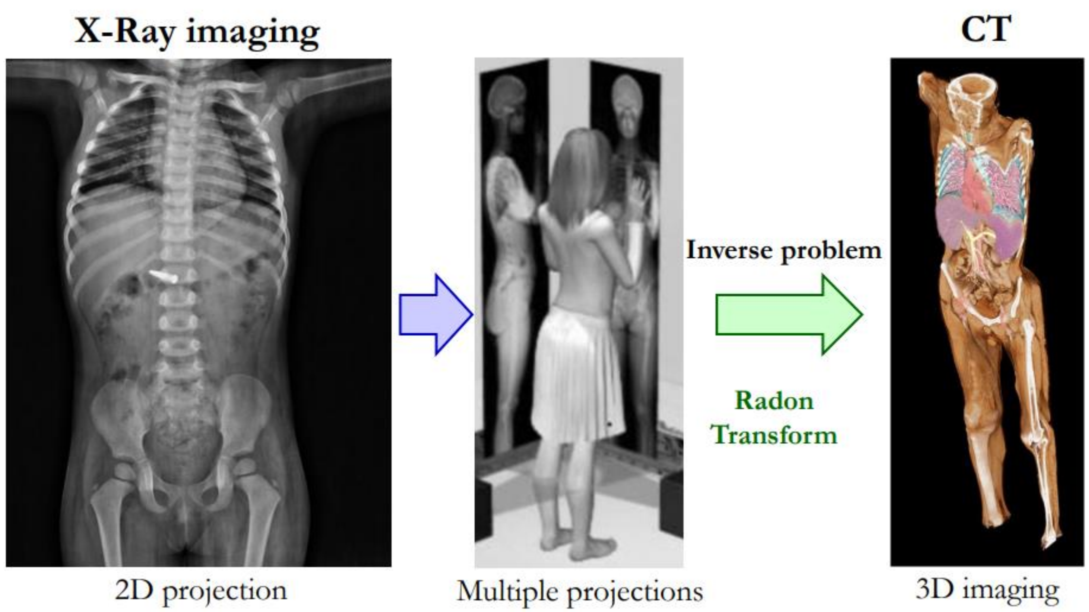
Reminders

- Make sure you have MATLAB and the toolboxes (**Signal Processing**, **Image Processing**) installed
- Download the zip file from LMS and extract all files into your MATLAB folder

Theory of CT

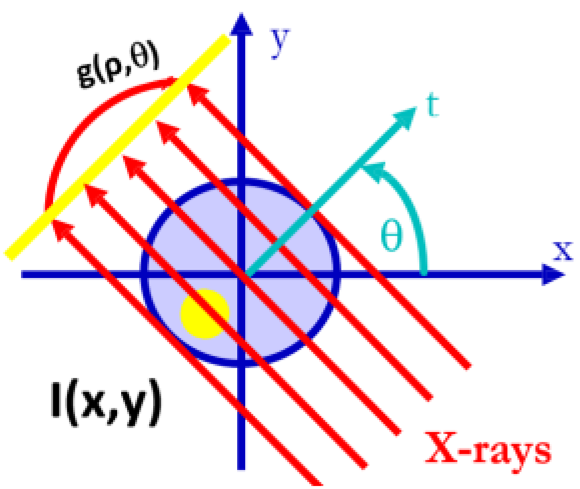
General theory of CT

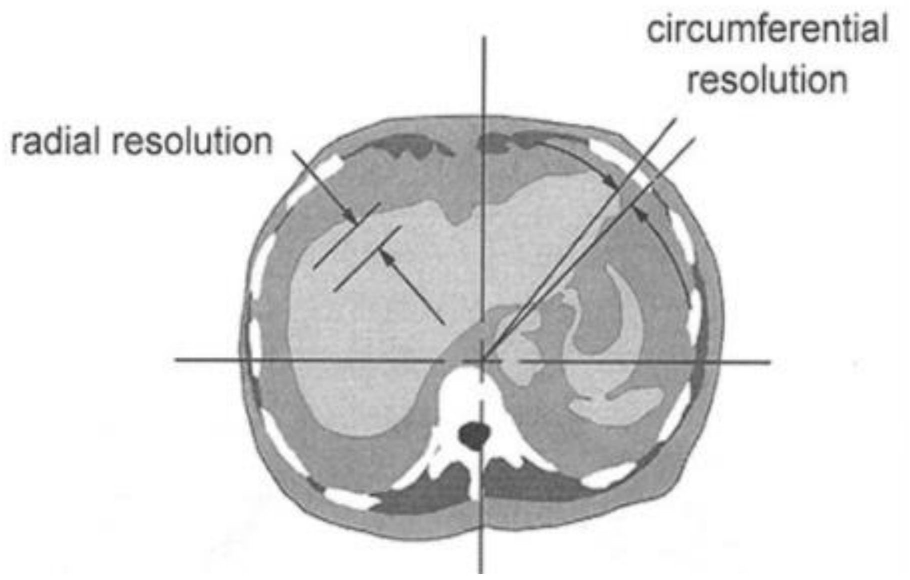
- X-ray projections are taken at multiple views
  - Attenuation due to different properties of tissue
- Solve the inverse problem to get tomographic information (CT = computed tomography)



Resolution of CT reconstruction

- **Number of rays** affects the radial component of spatial resolution
- **Number of views** affects the circumferential component of resolution

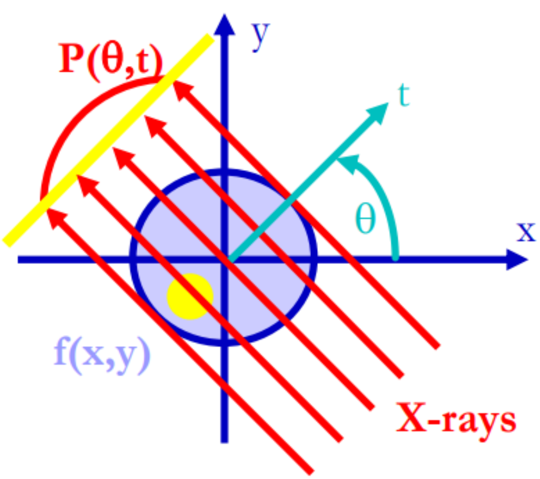


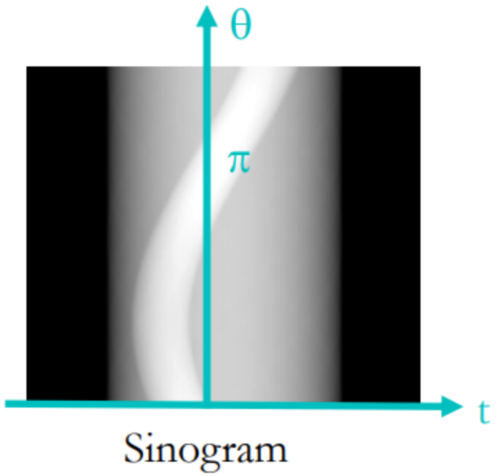


Radon transform

- Representation of the X-ray projection data in the form of a **sinogram**
- Indicates characteristics of the sample
  - Objects closer to the field of view produce a high amplitude in the sinogram

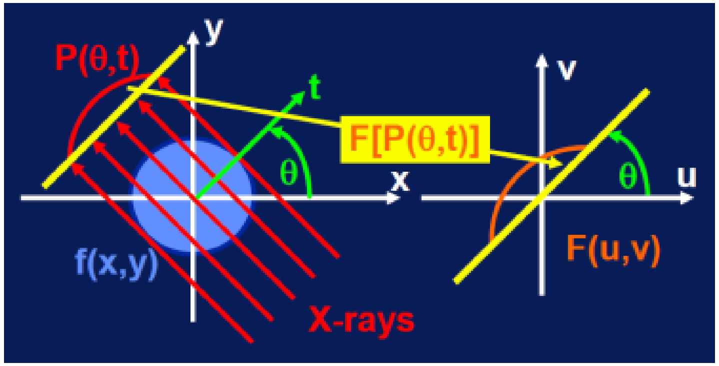
$$F(\theta, s) = = \int_{-\infty}^{+\infty} f(s\cos\theta + t\sin\theta, -t\cos\theta + s\sin\theta)dt$$





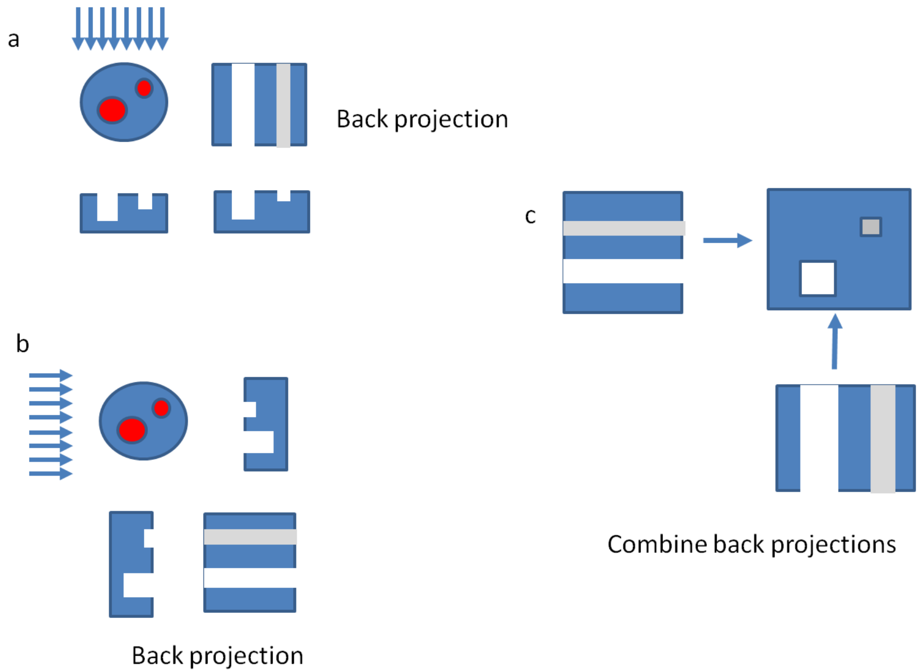
Inverse radon transform: Fourier slice theorem

- 1D Fourier Transform (FT) of the RT projection profile acquired at angle φ is equivalent to the value of the 2D FT of f(x,y) along a line at the inclination angle φ
- Putting together RT profiles at all acquisition angles yields the full 2D FT
- Image can be reconstructed using the inverse 2D FT



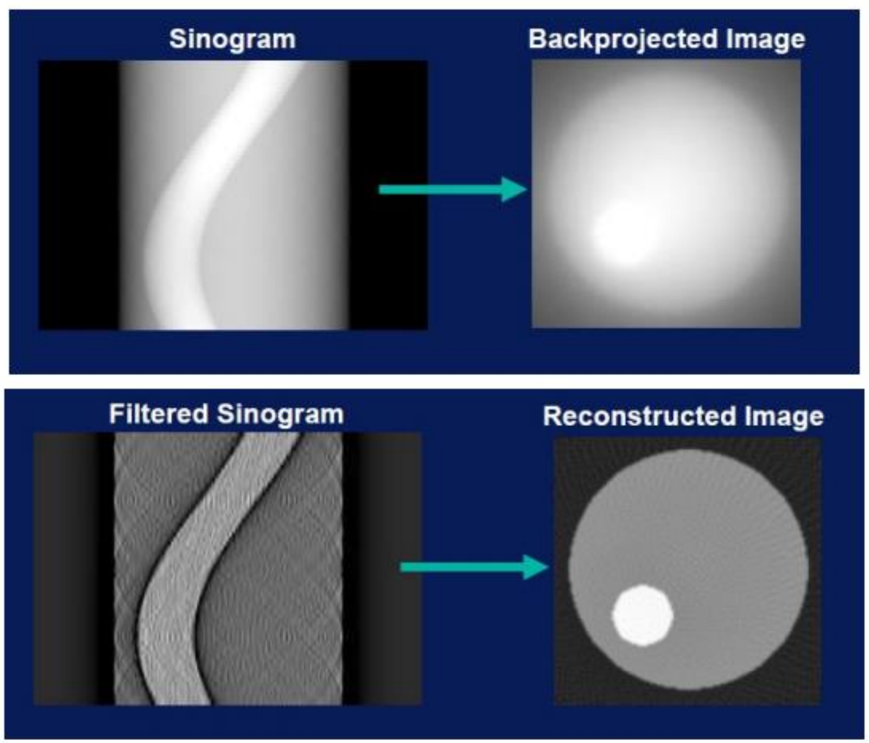
Back-projection

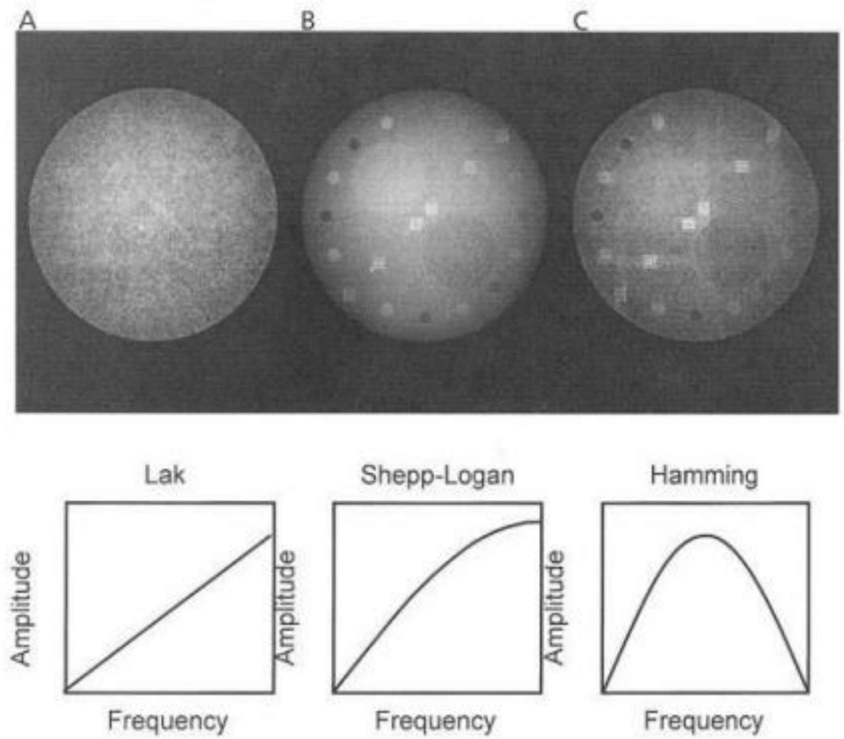
- Standard method of reconstructing CT slices
- Sinogram is used to back-project each view, then all views are combined to get the whole image



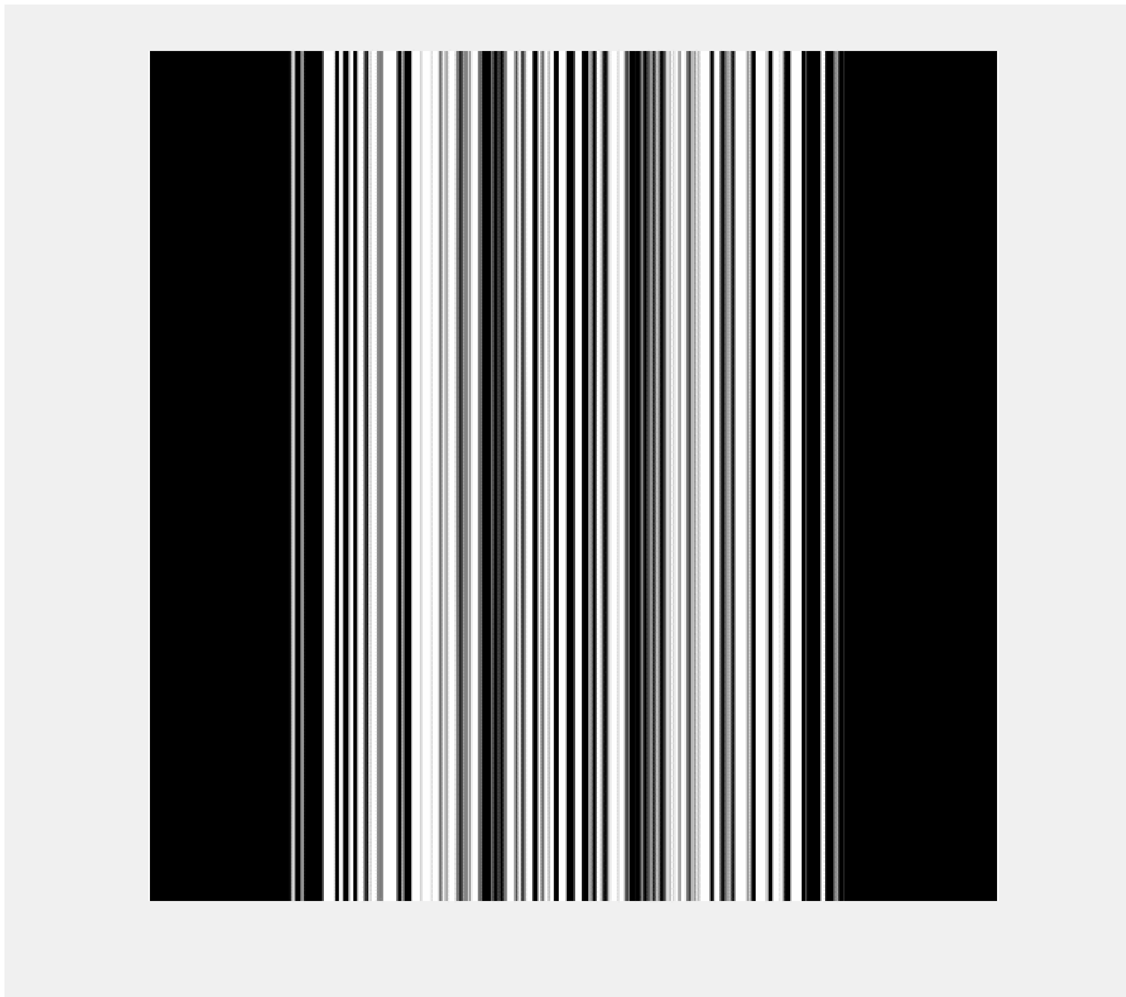
Filtered back-projection (FBP)

- Unfiltered back-projection from a normal sinogram can produce a blurry image
  - A filter is required in the sinogram space

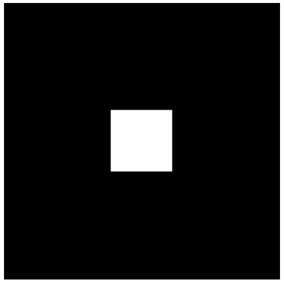
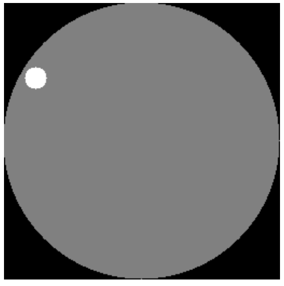




FBP in progress



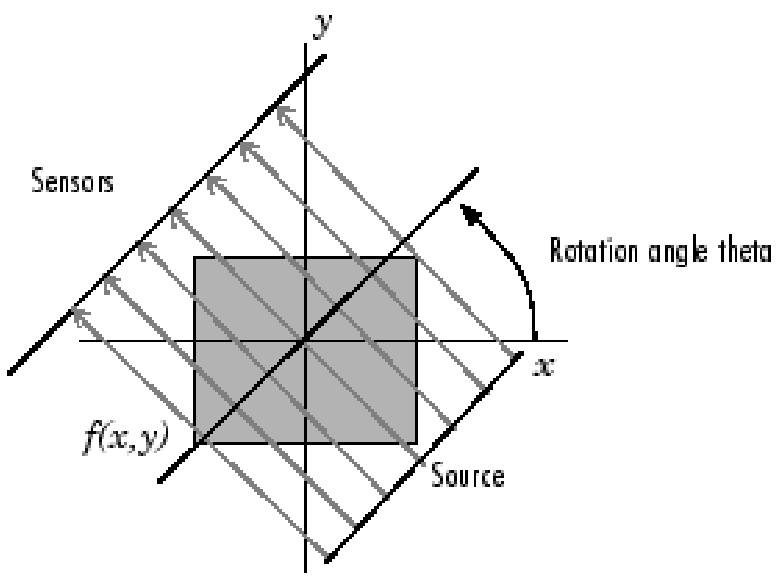
How can we use MATLAB for CT?
1. Parallel beam CT
2. Fan beam CT


Parallel beam CT

Parallel beam: ***radon***

- Beams (1 pixel apart) from the source are projected parallel to the detector and sample
- Parallel beams and detector are rotated around the center of the image at an angle theta θ



[R, xp] = radon(I, theta);

R = value
xp = detector locations
I = input image
theta = rotation angle

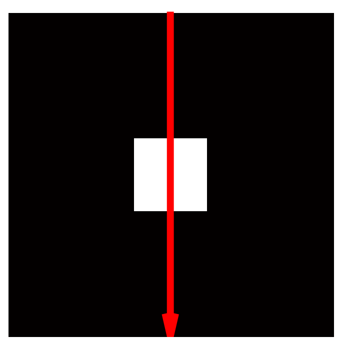
https://www.mathworks.com/help/images/radon-transform.html

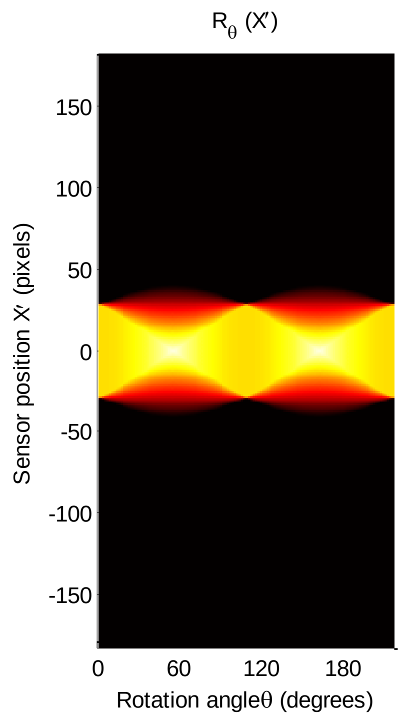
*Change p_type **(Line 5)** to 1, 2, or 3 for different sample types*

Example 1: Parallel beam

- Run Ex1_parallel.m
- As θ (red arrow) is changing, information is added to the sinogram!

Image domain

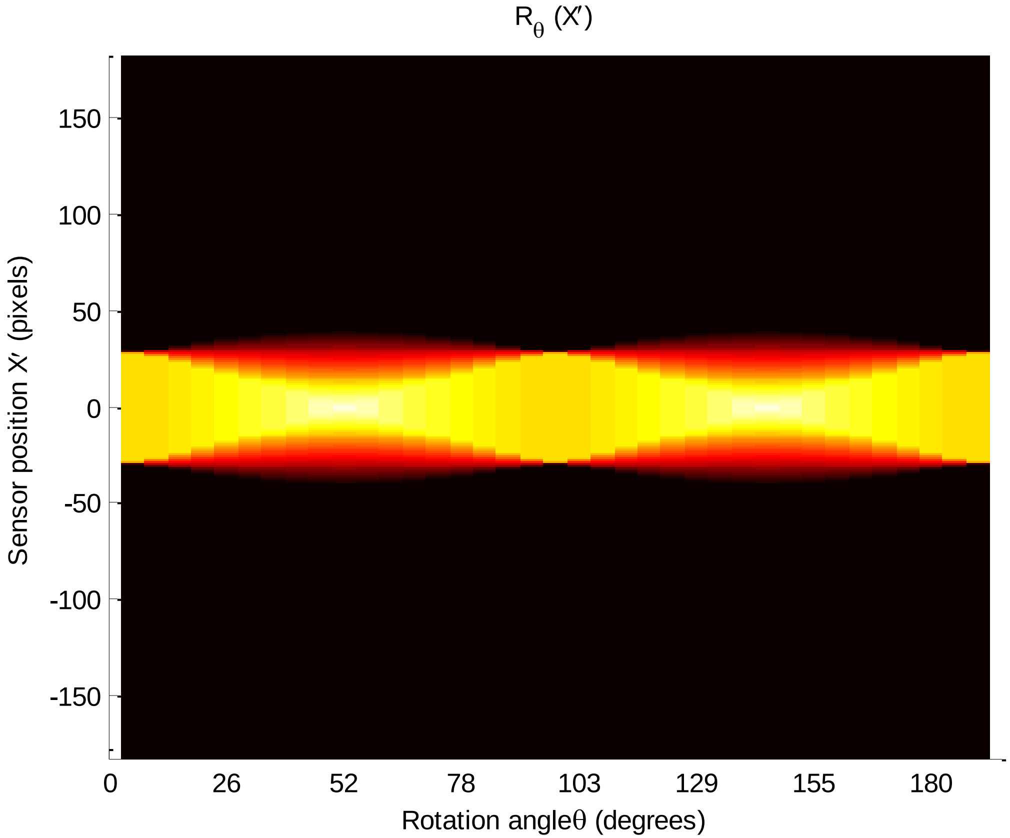




Sinogram domain

Example 1: Parallel beam

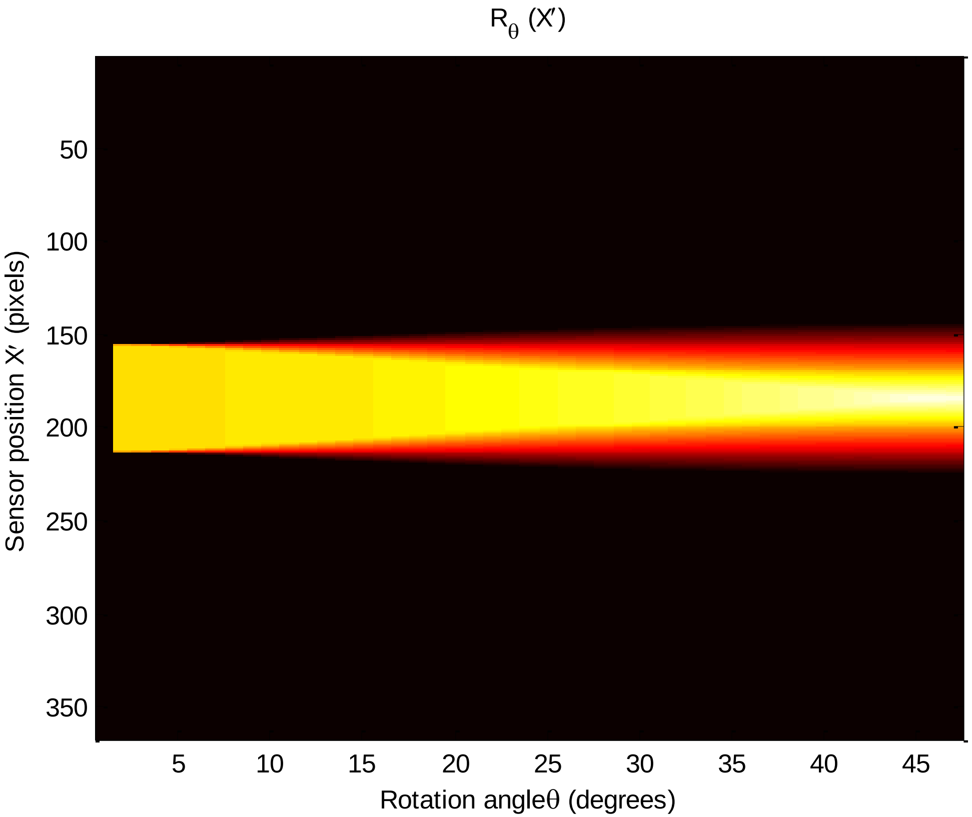
- What happens when we change the θ step (**Line 23**) to 5? What is happening here?



Collected angles are more discrete (fewer angular views, lower resolution)

Example 1: Parallel beam

- What happens if you change the max θ (**Line 22**) to 45? What is happening here?



The sinogram is truncated (only part of sample is scanned)

Parallel beam back-projection: ***iradon***

- Back-projection for parallel beam sinograms
- Filtered back-projection can be implemented

I = iradon(R, theta, *interp, filter*);

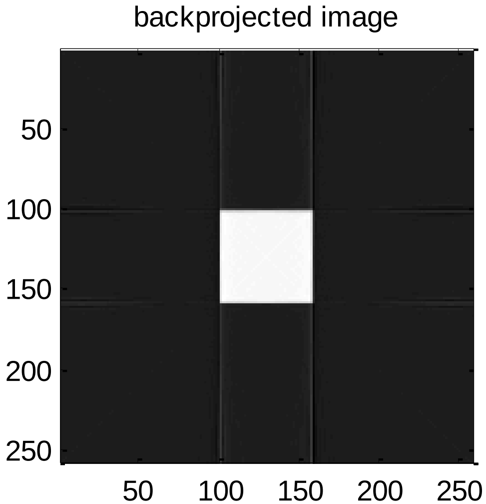
I = reconstructed image
R = sinogram
theta = rotation angle
interp = interpolation method
filter = filter to be used for FBP
(*interp*, *filter* are optional)

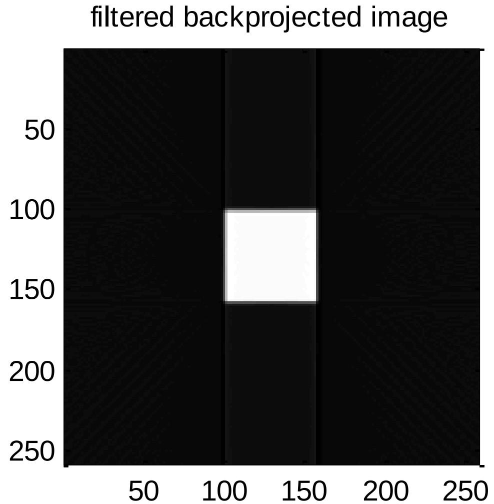
https://www.mathworks.com/help/images/the-inverse-radon-transformation.html

*Change p_type **(Line 5)** to 1, 2, or 3 for different sample types*

Example 2: Parallel beam BP

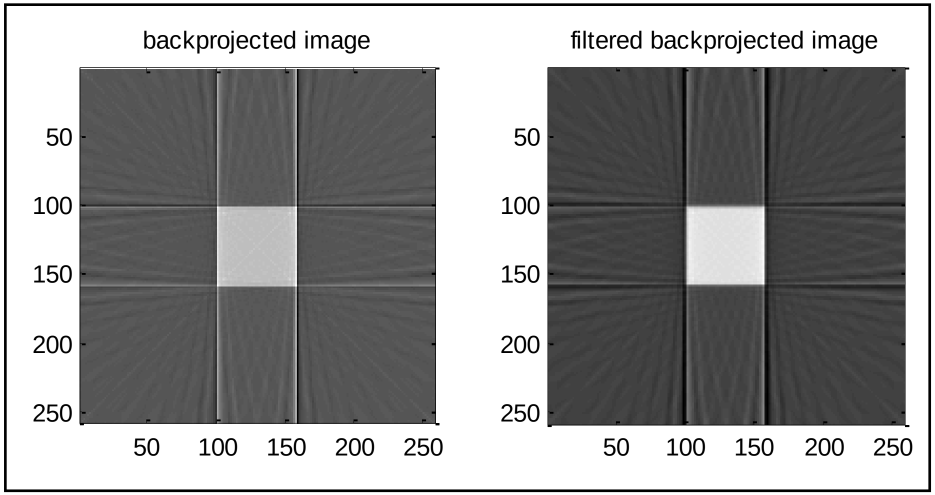
- Run Ex2_parallel_back.m
- **Line 32** implements normal BP (no filter)
- **Line 35** implements filtered BP
  - 'Hamming' can be replaced with other filter types
    - 'Ram-Lak'
    - 'Shepp-Logan'
    - 'Cosine'
    - 'Hann'





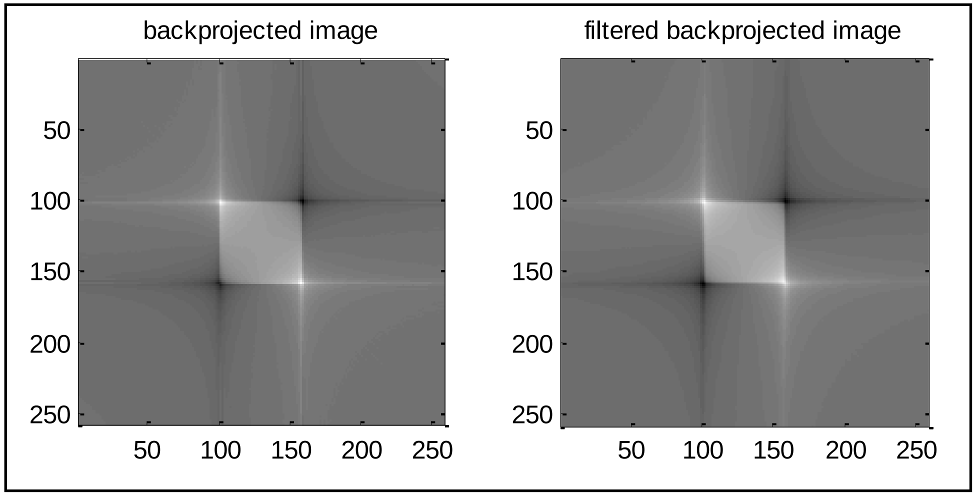
Example 2: Parallel beam BP

- What happens if you change the maximum θ (**Line 23**) or step (**Line 24**)?



max_theta = 180
step = 5

The reconstructions are less defined (discrete steps)



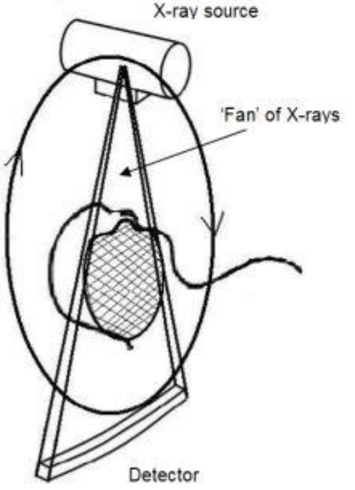
max_theta = 90
step = 1

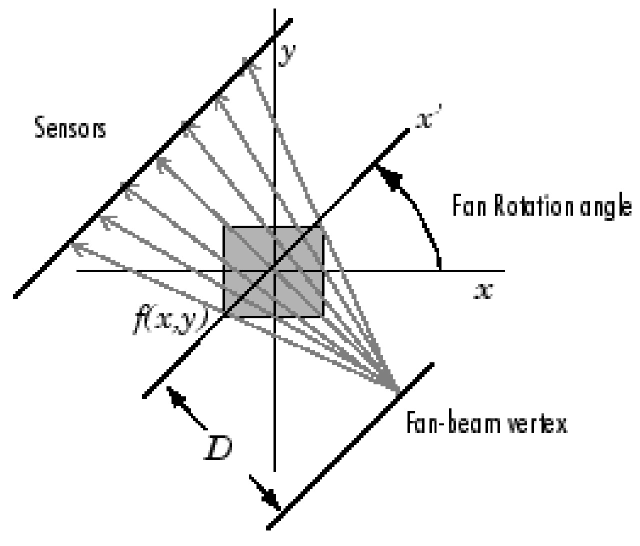
The reconstructions have lower resolution (less angles)

Fan beam CT

Fan beam: ***fanbeam***

- Source beams are projected in a fan shape from a beam vertex
- D is the distance between the fan beam vertex and sample's center of rotation
- Source and detector are rotated at an angle θ





Fan beam: ***fanbeam***

- Calculates projection data for a specified fan beam geometry
- Rotation angles (θ) fixed at 0 to 360 degrees

[F1, sensor_pos1, fan_rot_angles1] = fanbeam(P, D, 'FanSensorSpacing', dsensor1);

F1 = output
sensor_pos1 = sensor positions
fan_rot_angles1 = fan rotation angles
P = input image
D= distance to object
FanSensorSpacing = specific property
dsensor1= spacing between sensors
(*FanSensorSpacing*, *dsensor1* are optional)

Fan beam FBP: ***ifanbeam***

- Converts the fan-beam data to parallel beam projections
- Uses the filtered back projection algorithm to perform the inverse Radon transform

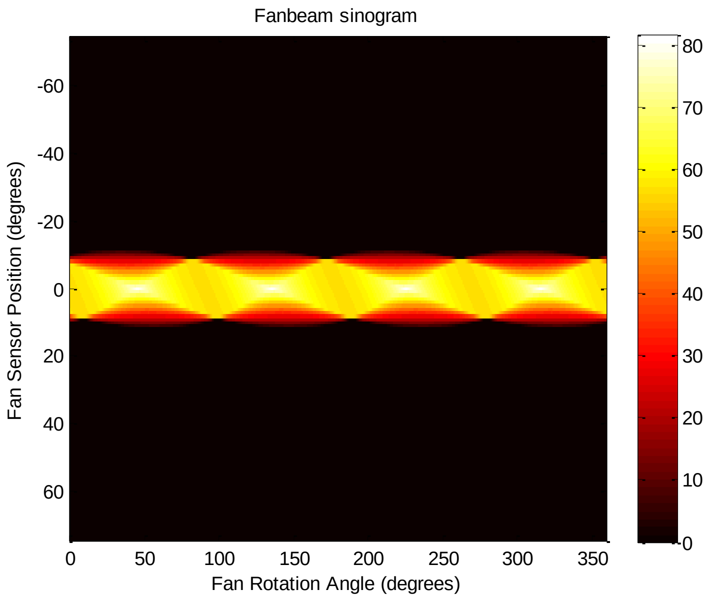
Ifan1 = ifanbeam(F1, D, ‘FanSensorSpacing’, dsensor1);

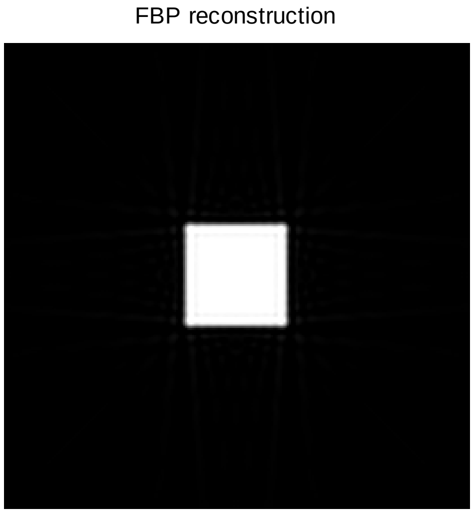
Ifan1 = output
F1 = sinogram
D= distance to object
FanSensorSpacing = specific property
dsensor1 = spacing between sensors
(*FanSensorSpacing*, *dsensor1* are optional)

*Change p_type **(Line 5)** to 1, 2, or 3 for different sample types*

Example 3: fan beam CT

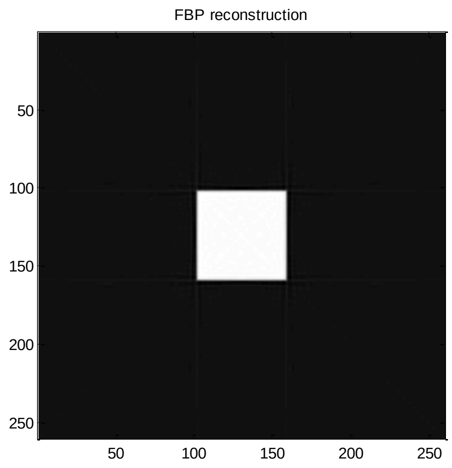
- Run Ex3_fanbeam.m
- D (**Line 25**) is slightly larger than half the diagonal distance of image (convention),
- Dsensor = 1 (**Line 26**)



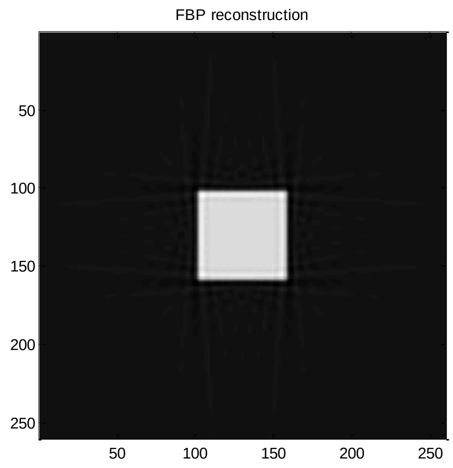


Example 3: fan beam CT

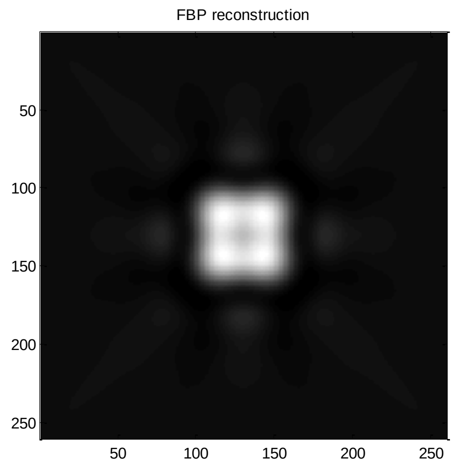
- What happens if you change the sensor spacing (**Line 26**) from 1 to 5? From 1 to 0.5? (D unchanged)



Dsensor = 0.5



Dsensor = 1



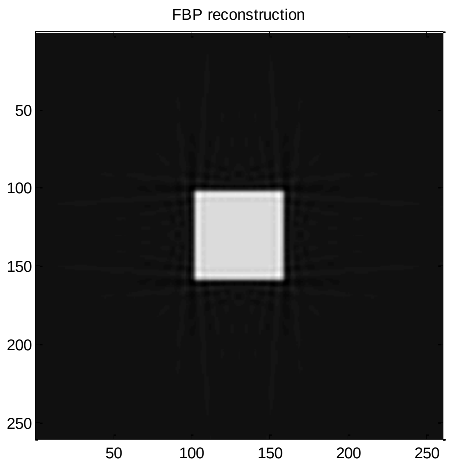
Dsensor = 5

The resolution is related to the sensor spacing (high spacing = low resolution)

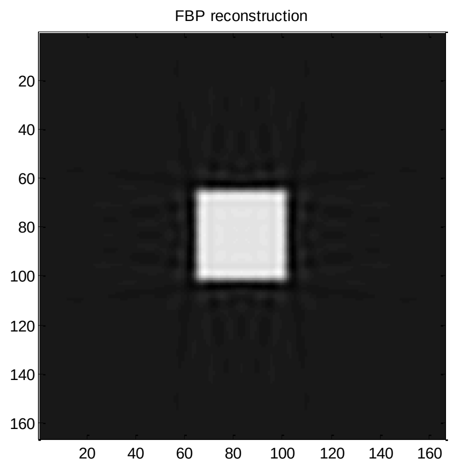
Example 3: fan beam CT

- What happens if you increase D in **Line 28**? (Dsensor = 1)

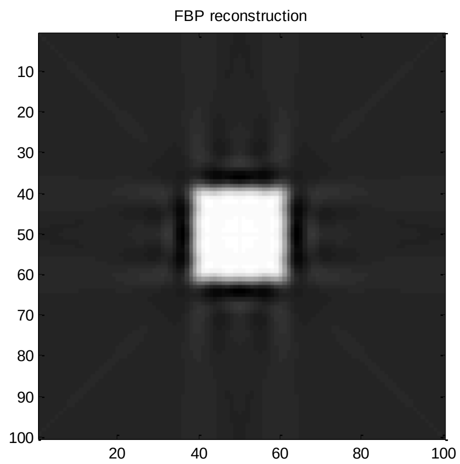
```
28 -      [F, pos, theta] = fanbeam(img,D,'FanSensorSpacing',Dsensor);
```



D = default (~191)



D = 300



D = 500

Higher source-object distance gives lower reconstruction resolution

BB13 Homework

Read the web page carefully and run the codes on your PC:

http://www.mathworks.com/help/images/radon-transform.html?refresh=true

Then write a similar page with an ellipse as your object (instead of the square).

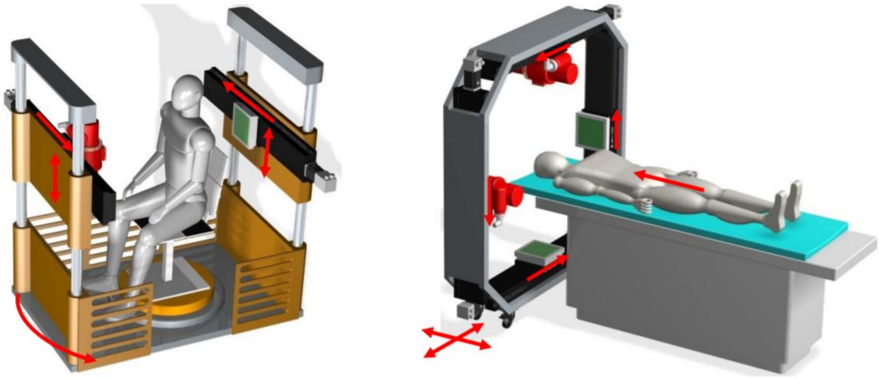
Use the iradon function to reconstruct your ellipse.

Due Date: Tuesday 3/20 (11:59PM)

BB14 Homework

Green Book

1.14, 1.15 and 1.18



Optional:

As an Art_X Project, Please Design Portable CT Scanner in an Auto-driving Car, or a CT Scanner for a Novel Application.

Due Date: Friday 3/23 (11:59PM)

https://arxiv.org/ftp/arxiv/papers/1312/1312.6046.pdf
http://content.iospress.com/articles/journal-of-x-ray-science-and-technology/xst00453

Thank you