**Subject Name: Biomedical Instrumentation Design II 2**

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**Lecture No.: 5**

**Lecture Title: Image reconstruction.**

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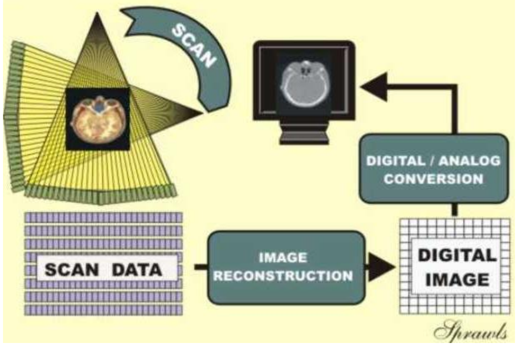
## Image Reconstruction

- Each time the x-ray tube is activated, information is gathered and fed into the system computer.
- The computer processes thousands of bits of data from each scan acquired to create the CT image.
- These data must be saved to a computer file so that the information will be available for use in forming an image.
- These stored data can later be retrieved and manipulated.



- Raw data (scan data) are the thousands of bits of data acquired by the system with each scan and waiting to be made into an image. Raw data requires a vast amount of hard disk space.
- *Image reconstruction*: the process of using raw data to create an image.
- *Prospective reconstruction*: the reconstruction that is automatically produced during scanning.
- *Retrospective reconstruction*: the same raw data may be used later to generate a new image.
- Because raw data include all measurements obtained from the detector array, various images can be created from the same data.

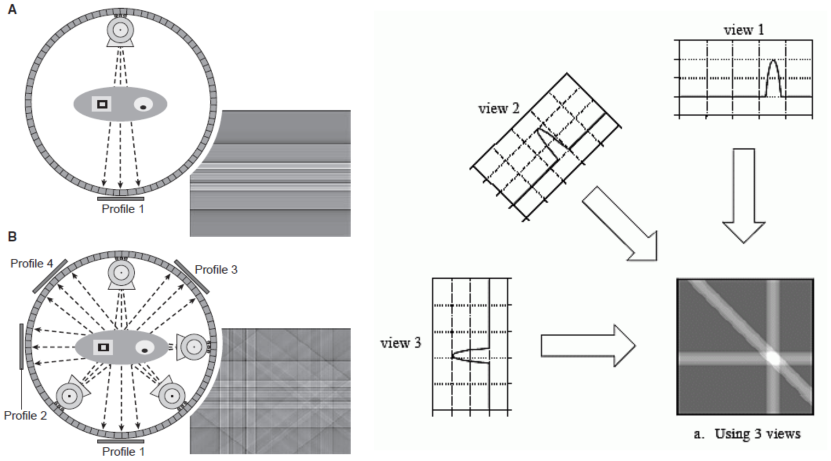
- The computer assigns a single value (Hounsfield unit) to each pixel to form an image.
- The density number is the average of all attenuation measurements for that pixel and represents the proportional amount of X-ray energy that passes through the anatomy and strikes the detector.
- Once the data are averaged so that each pixel has a single associated value, an image can be formed.
- The data included in this image are appropriately called image data that require approximately one-fifth of the computer space needed for raw data.

***Discuss the following:***

"If only image data are available, data manipulation is limited."

- To convert raw attenuation data into standardized grayscale pixels, the computer calculates the Hounsfield Unit (HU) for each voxel relative to water. The Standardization Formula:
- $$HU = 1000 \times \frac{\mu_{tissue} - \mu_{water}}{\mu_{water}}$$
- Where μ represents the linear attenuation coefficient of the material.
- Example: If the linear attenuation coefficient of water ($\mu_{water}$) is 0.19 $cm^{-1}$ at a specific X-ray energy, and a pixel contains dense bone with $\mu_{bone}$=0.38 $cm^{-1}$ , what is the displayed HU?
- Answer: HU=1000×((0.38−0.19)/0.19)=+1000 HU
- This mathematical relationship dictates that distilled water is always calibrated to exactly 0 HU, air to −1000 HU, and dense bone to +1000 HU or higher.

- As the x-ray tube travels along its circular path, continuous x-ray energy is generated and passes from the x-ray tube to the detector in a path called ray.
- The DAS reads ray sum (each arriving ray and measures how much of the beam is attenuated), which is known as a ***view***.



- The DAS reads ray sum (each arriving ray and measures how much of the beam is attenuated), which is known as a ***view***.
- To form an image, The CT system accounts for the *attenuation properties* of each ray sum and correlates them with the *position of the ray*.
- The result of this type of correlation is called an ***attenuation profile*** for each ***view*** in the scan.
- The information from all of the profiles is projected onto a matrix.
- This process of converting the data from the attenuation profile to a matrix is called ***back projection.***

- A ray sum represents the total attenuation of an X-ray beam as it passes through a non-homogeneous patient body. This physical process is modeled by the Beer-Lambert Law.
- The Governing Equation: $$I = I_0 e^{-\sum_{i=1}^{n} \mu_i x}$$
- Where:
- I = Transmitted x-ray intensity (measured by the DAS detector).
- $I_0$ = Initial X-ray intensity emitted from the tube.
- $\mu_i$ = Linear attenuation coefficient of the i-th tissue voxel along the ray path.
- x = Thickness of each voxel.
- To reconstruct the image, the computer takes the natural logarithm of the ratio ($\ln(I_0/I)$) to isolate the sum of the individual attenuation coefficients ($\sum\mu_i$) to create the attenuation profile.

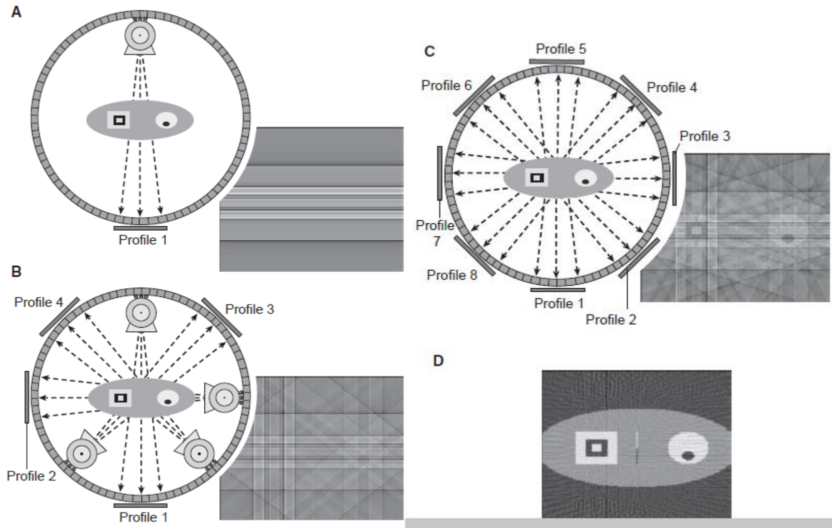
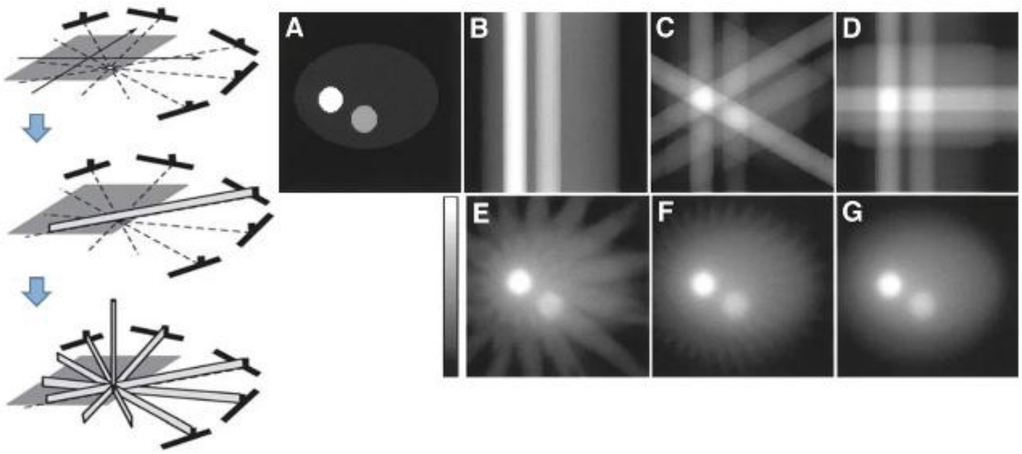
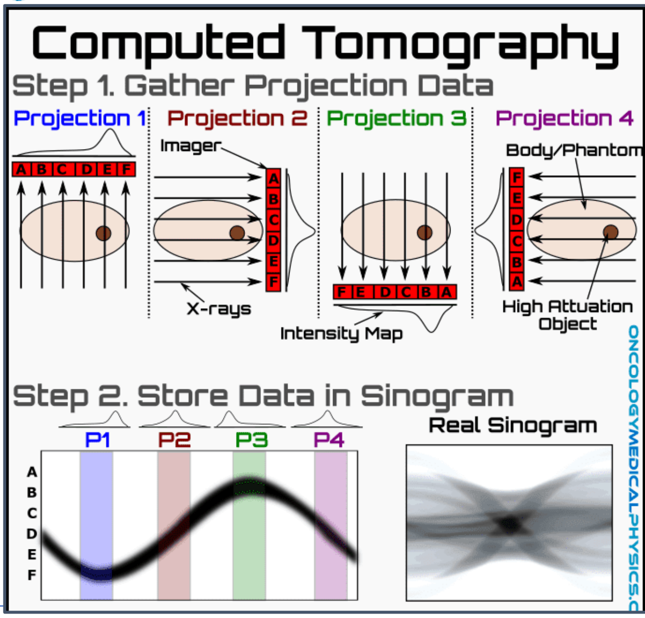



**FIGURE 3-3** Data are converted from the attenuation profiles to a matrix with a process known as back projection. **A.** With only one back projection, not much information about the object scanned is revealed. **B.** With four back projections, some details start to emerge. **C.** With eight back projections, more details are visible. **D.** With 60 back projections, the image finally resembles the objects scanned.




Computed Tomography
Step 1. Gather Projection Data
Projection 1
Projection 2
Projection 3
Projection 4
Imager
Body/Phantom
A B C D E F
X-rays
Intensity Map
High Attuation Object
Step 2. Store Data in Sinogram
Real Sinogram
P1
P2
P3
P4
A
B
C
D
E
F
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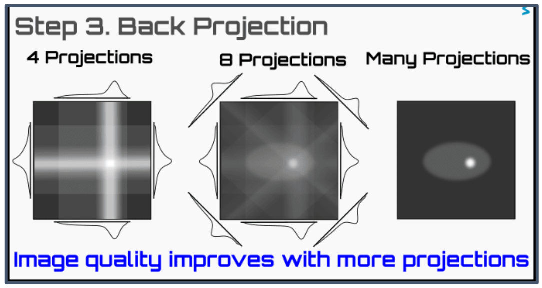
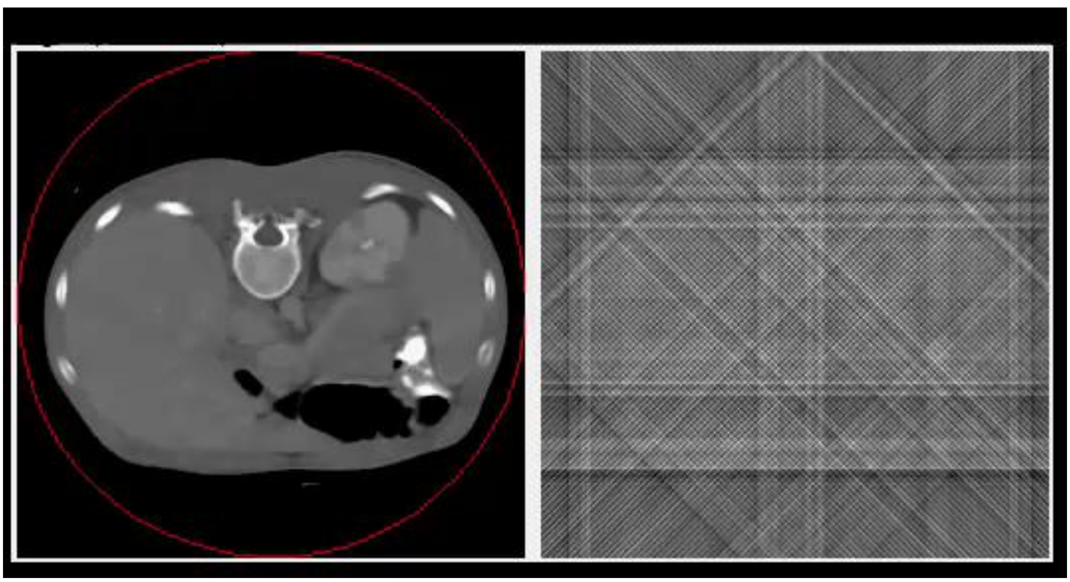

Step 3. Back Projection
4 Projections
8 Projections
Many Projections
Image quality improves with more projections



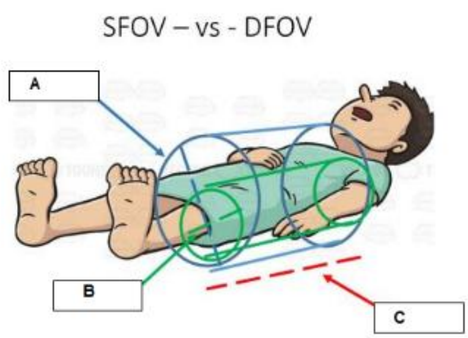
- During back projecting data onto a matrix, streak artifacts are produced in a star pattern on the image.
- Convolution process is a complicated mathematical steps that filters the scan data before back projection and is used to reduce streak artifacts.
- Filtered back-projection algorithms use Fourier theory to reduce statistical noise and create an image that is pleasing to the eye.
- The filter selection depends on which parts of the data must be enhanced or suppressed.
- Smoothing filters reduce the difference between adjacent pixels. This can help to reduce the appearance of artifacts but reduce spatial resolution.
- Conversely, some filters accentuate the difference between neighbouring pixels to optimize spatial resolution, but must make sacrifices in low contrast resolution.

***Discuss:***

- Changing the window setting merely changes the way the image is viewed. Changing the algorithm will change the way the raw data are manipulated to reconstruct the image

- Scan field of view (SFOV), also called calibration field of view, determines the area within the gantry from which the raw data are acquired.
- By selecting a 25 cm SFOV, a technologist acquires data in a circular shape, with a diameter of 25 cm, lying in the absolute center, or isocenter, of the gantry where the patient is positioned.
- SFOV selection determines the number of detector cells collecting data.
- Data are not acquired on everything within the gantry!
- If the gantry opening is 70 cm but the largest SFOV available is 48 cm, there will be a ring in which data cannot be collected.

**A**. SFOV: Scan Field of View, the are within the gantry from which the raw data are acquired
**B**. DFOV: Display Field of View, the section of data selected for image display on a monitor
**C**. Scan Length: set by the rad during planning and determines the start and end of the length of data along the z-axis



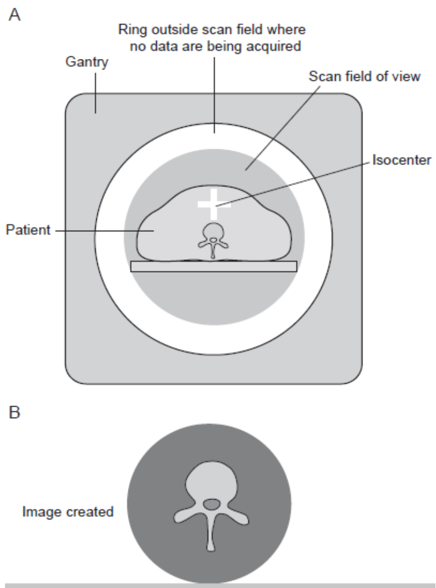



**FIGURE 3-4** **A.** Raw data are collected within the scan field of view. **B.** Image data are confined to those displayed on the monitor.

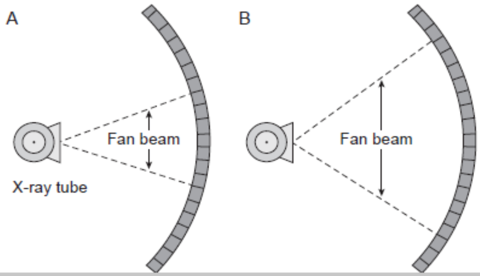



**FIGURE 3-5** The selection of scan field of view determines the number of detector cells collecting data.

- Display field of view (DFOV; also called zoom or target) determines how much of the collected raw data is used to create an image.
- For example, if a lumbar spine is correctly scanned with a large SFOV to include the entire body, but the operator chooses to target the image so that the vertebrae occupy most of the screen, the rest of the patient's abdomen is not visualized on the image.
- Changing the DFOV will affect image quality by changing the pixel size.
- To select the amount of raw data to be displayed on the CT image, the operator selects some number (in either centimeters or millimeters depending on the scanner manufacturer) as the DFOV.
- Because the data selected for the DFOV are a subset of all the scan data available, the DFOV cannot be larger than the SFOV

- The Display Field of View (DFOV) directly affects the spatial resolution of the final image. The Formula:

Pixel Size=DFOV/Matrix Size

- **Example:** A technologist scans a patient using a standard 512×512 reconstruction matrix. What happens to the pixel size if the DFOV is set to 400 mm (to view the whole abdomen) versus zooming in to a DFOV of 150 mm (targeted specifically to the lumbar spine)?
- **Abdomen (Large DFOV):** 400 mm / 512=0.78 mm per pixel.
- **Spine (Small DFOV):** 150 mm / 512 =0.29 mm per pixel.
- Conclusion: Reducing the DFOV significantly reduces the physical size of each pixel, thereby increasing the spatial resolution and allowing smaller pathologies to be detected.

- Choosing the optimal display field improves the detectability of abnormalities.
- Selecting too large a DFOV makes the image appear unnecessarily small, in addition to the inherent difficulty in viewing smaller images, more data are included in each pixel and spatial resolution decreases.
- On the other hand, too small a DFOV may

exclude necessary patient anatomy.

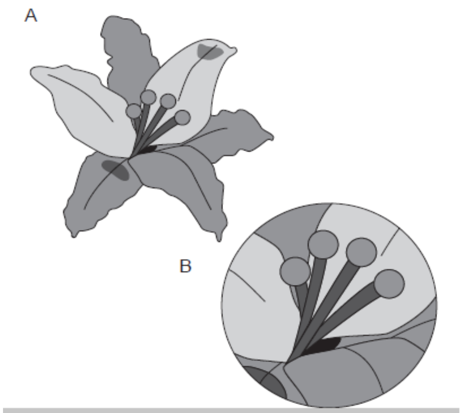



**FIGURE 3-6** Selecting the display field of view determines how much of the raw data are used to create an image. Display field works like the zoom on a camera and can be used to show the entire area or to display a specific region of interest in greater detail.


THANK YOU