



Subject Name: Biomedical Instrumentation Design II 2

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Lecture Title: Data Acquisition, Part 2.

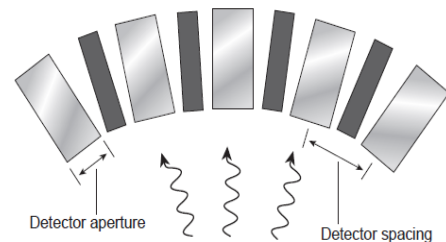
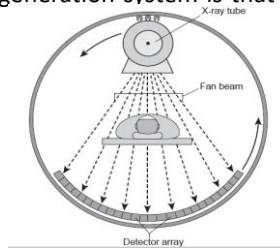


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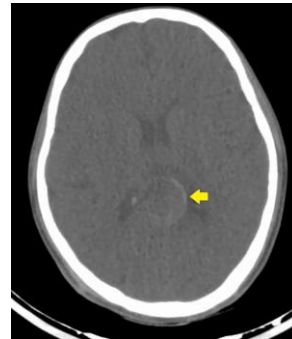
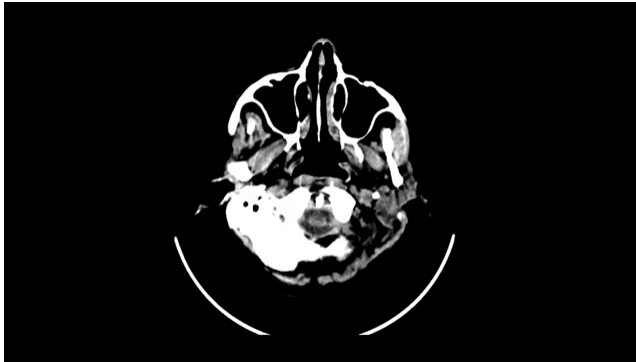
Data Acquisition, Part 2

- Third-generation CT scanner.
- Reference detectors are typically located at either end of the detector array to measure the unattenuated x-ray beam.
- The rotating detector design allows all of the readings that make up a view to be recorded instantaneously and simultaneously >>> thus reducing scan times and patient motion artifacts resulting from patient motion.
- An advantage of the third-generation system is that the tube is directly focused on the detector array.

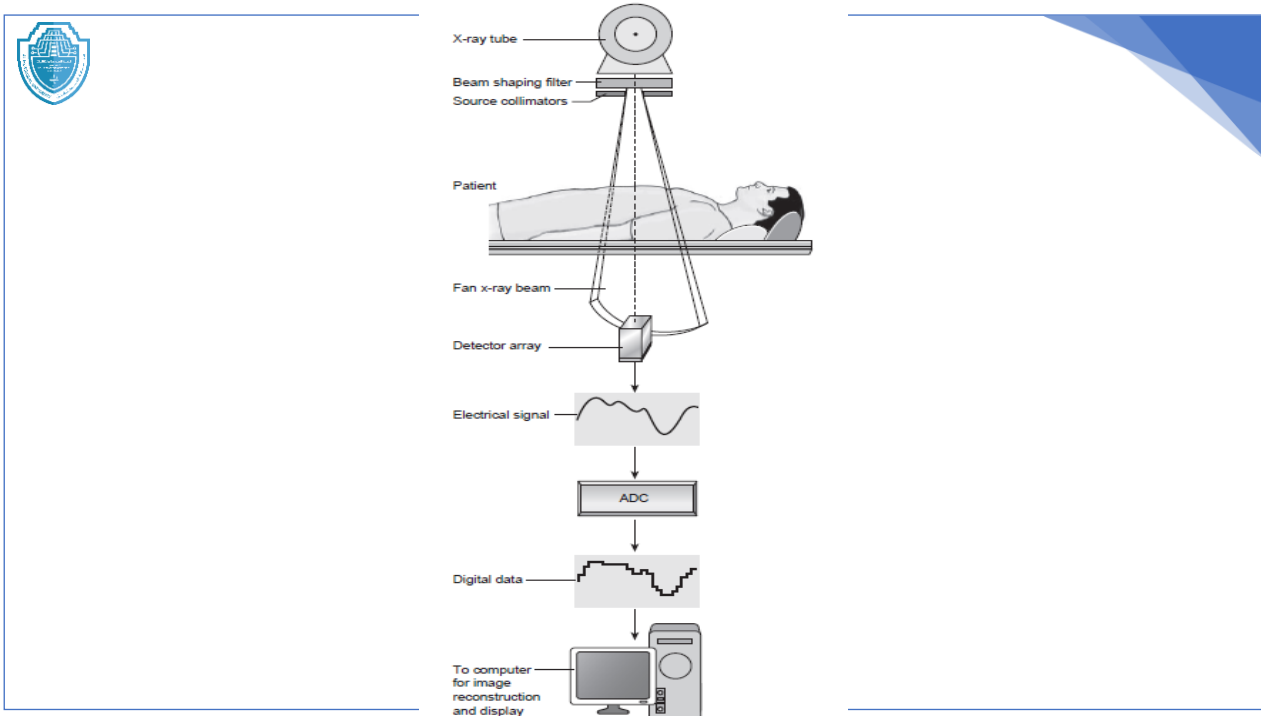




- A disadvantage of the third-generation design is the more frequent occurrence of ring artifacts. Because the same bank of detectors is used repeatedly, *even a very small misalignment of a single detector will result in a visible ring artifact.*



- **Detector Electronics**
- X-ray photons that strike the detector must be measured, converted to a digital signal, and sent to the computer.
- This is accomplished by the data-acquisition system (DAS), which is positioned within the gantry near the detectors.
- Signals emitted from the detectors are analog (electric), whereas computers require digital signals. Therefore, one of the tasks of the DAS is to convert the analog signal to a digital format.
- To measure the x-ray photons that have penetrated the patient, the DAS samples the detectors as many as 1,000 times per second.



X-ray DAS Data Volume Calculation

- The Data Acquisition System (DAS) must handle a massive influx of analog signals. To understand the required bandwidth and processing power, we can calculate the exact number of data points digitized per slice.
- Formula: $\text{Data Points per Slice} = \text{Number of Detectors} \times \text{Sampling Rate} \times \text{Rotation Time}$
- Example: A 3rd-generation CT scanner features an array of 850 detectors. The DAS samples the analog signals at a rate of 1000 Hz. If the gantry completes one full rotation in 0.5 seconds, how many individual attenuation readings are sent to the computer for a single slice?
- Solution: $\text{Data Points per Slice} = 850 \times 1000 \times 0.5 = 425,000$



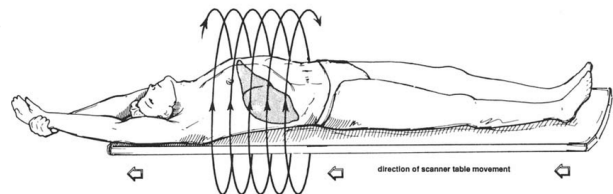
X-ray DAS Data Volume Calculation

- A DAS data point is *NOT* a pixel, and its unit is *NOT* a Hounsfield Unit (HU).
- At the DAS stage, these data points are just raw X-ray intensity readings (often called "raw data" or "projection data").
- The computer must take hundreds of thousands of these raw ADC counts and run them through complex mathematical reconstruction algorithms (such as Filtered Back Projection) before they are finally converted into Hounsfield Units (HU) and pixels that make up the final CT image.



• **Patient table**

- The patient lies on the table (or couch) and is moved within the gantry for scanning.
- The process of moving the table by a specified measure is most commonly called incrementation, feed, step, or index.
- Helical CT table incrementation is quantified in millimeters per second because the table continues to move throughout the scan.
- The degree to which a table can move horizontally is called the scannable range, and will determine the extent a patient can be scanned without repositioning.





Helical Pitch Calculation

- Pitch defines the relationship between patient table movement and the X-ray beam width. It is a critical parameter that engineers use to balance image resolution against patient radiation dose.
- Formula: $\text{Pitch} = \text{Table feed per rotation} / \text{Total collimation width}$
- Example: A 64-slice CT scanner has a detector width of 0.625 mm per slice. If the patient table moves 30 mm per 360-degree rotation, what is the pitch?
- Solution: Total collimation width = 64 slices \times 0.625 mm = 40 mm
- Pitch = 30/40 = 0.75
- Note: Because the pitch is less than 1, overlapping data acquisition occurs, yielding higher image quality but increasing the radiation dose.



CT GANTRY CONTROL PANEL

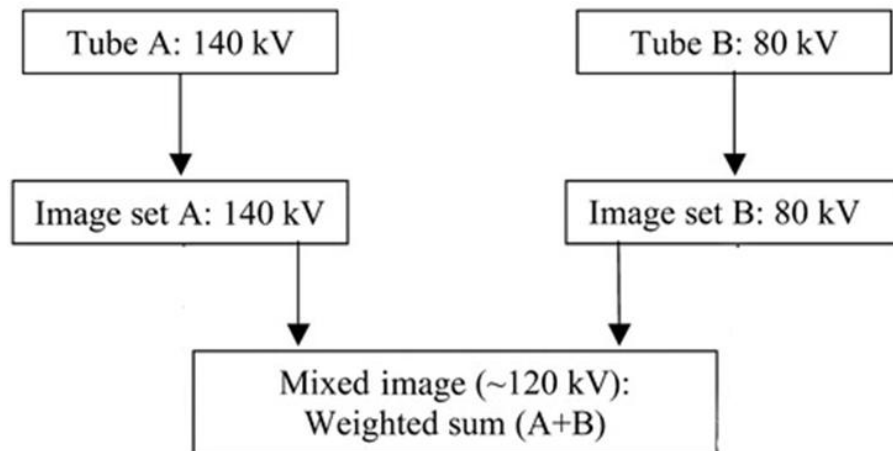
1. Gantry Tilt (+/-30 degrees).
2. Laser Alignment Lights on/off.
3. Couch in/out.
4. Free (manual) Couch Movement.
5. Zero Couch Position.
6. Couch up/down.
7. Home Button (couch out & down).





- **Dual Energy CT (DECT)**

- Dual-energy CT, also known as spectral CT, is a computed tomography technique that uses two separate x-ray photon energy spectra, allowing the interrogation of materials that have different attenuation properties at different energies.
- Whereas conventional single-energy CT produces a single image set, dual-energy data (attenuation values at two energy spectra) can be used to reconstruct numerous image types:
 - Weighted average images (simulating single energy spectra).
 - Virtual monoenergetic images (attenuation at a single photon energy rather than a spectrum).





- **material decomposition images:** is a method for differentiation and quantification of materials in a sample and it utilizes the energy dependence of the linear attenuation coefficient, i.e. mapping or removing substances of known attenuation characteristics, such as iodine, calcium, or uric acid):
- virtual non-contrast images (iodine removed).
- Iodine concentration (iodine maps): used to detect pulmonary embolism (PE) with CT angiography.
- Calcium suppression (calcium removed (CaSupp)): used to observe bone marrow edema by removing calcium components from the image.
- Uric acid suppression (uric acid removed): used for the diagnosis of gout. It is a good noninvasive alternative to synovial fluid aspiration.



Material Decomposition in Dual Energy CT (DECT)

- Dual Energy CT differentiates materials by exploiting how their linear attenuation coefficients change at different energy levels. By scanning at two distinct energy spectra (e.g., 80 kV and 140 kV), the system establishes a system of linear equations to solve for the exact concentrations of two base materials, such as iodine and water.
- The Mathematical Model: The total measured attenuation μ at a specific energy level E is the sum of the attenuation contributions from the base materials:

$$\mu(E1)=c_{\text{water}}\mu_{\text{water}}(E1)+c_{\text{iodine}}\mu_{\text{iodine}}(E1)$$

$$\mu(E2)=c_{\text{water}}\mu_{\text{water}}(E2)+c_{\text{iodine}}\mu_{\text{iodine}}(E2)$$

- The $E1$ and $E2$ represent the two different x-ray tube energies (e.g., 80 kV and 140 kV).
- c represents the unknown concentration of the material.
- Because μ_{water} and μ_{iodine} are known constants at these specific energies, the computer easily solves these two equations to isolate the exact concentration of iodine, allowing for the generation of "iodine maps" or "virtual non-contrast" images.



THANK YOU

