MODULE 5
CT SCAN

INTRODUCTION

- Computed Tomography (CT) scan is also called as Computer axial Tomography (CAT) scan. It provides detailed, cross sectional views of all types of tissues in the human body.
- Tomography is derived from Greek word “tomos” meaning ‘slice’ and “graphen” meaning ‘to write’.
- CT scan is one of the best imaging method for analysing the chest, brain and abdomen. It is often used for the diagnosing various cancers like lung, liver and pancreatic cancers. The image reveals to a physician to confirm the presence of a tumour and to measure its size, location and the extent of damage for the near by tissue.
- It uses special x-ray equipment to obtain a set of image data at different angles around the human body. The set of data processed in a computer to show a cross – section of human body tissues and organs
- By using CT scan we can produce clear 2-D or 3-D cross sectional images of deep internal organs.

CT SCAN PRINCIPLE OF OPERATION

SIMPLE BLOCK DIAGRAM

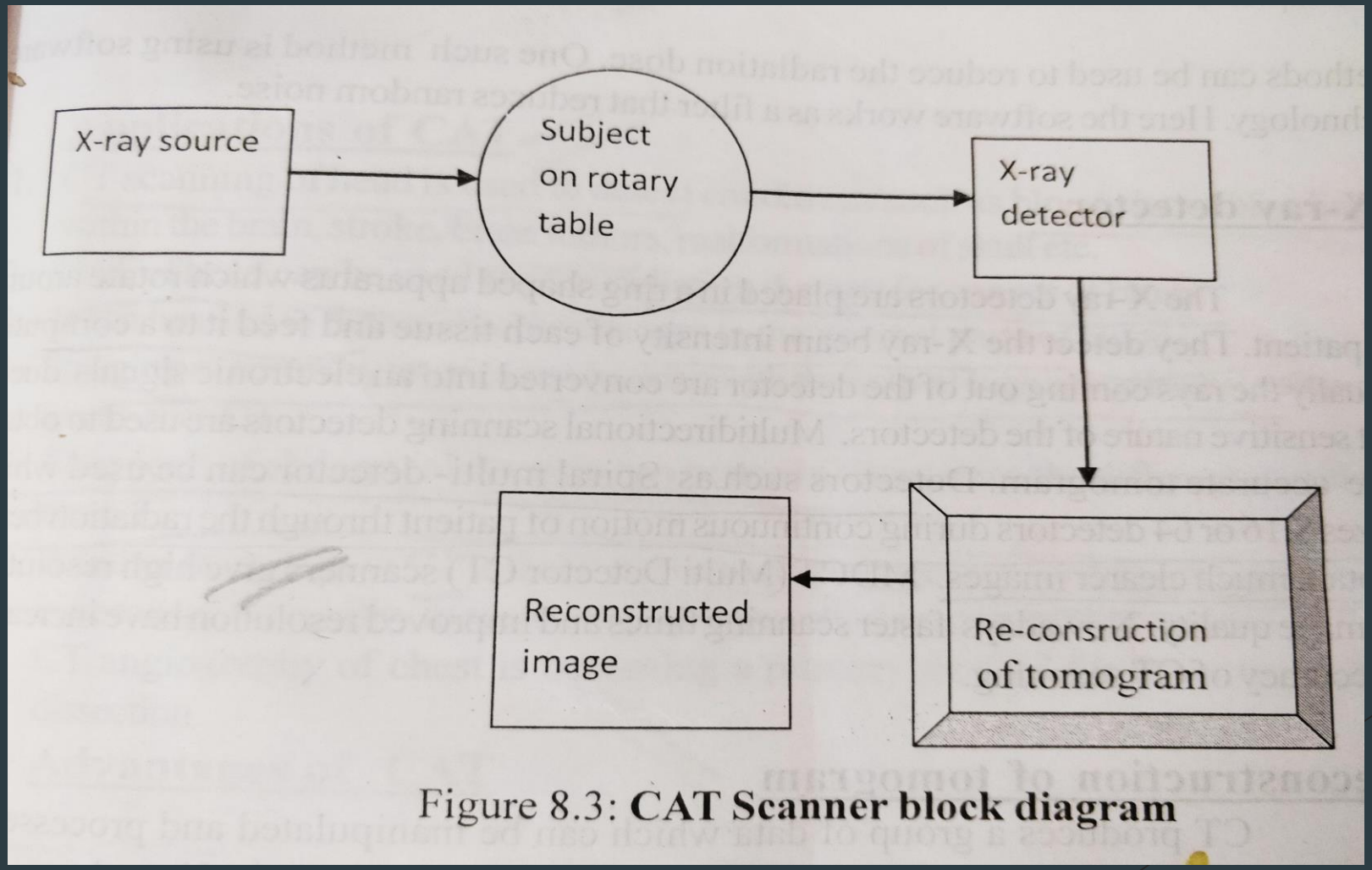

Figure 8.3: **CAT Scanner block diagram**

- In CT scan x-ray slice data is generated using an x-ray source that rotates around the subject. X –ray sensors are placed on the opposite side of the circle from the x -ray source.
- The sensors are Scintillation detectors based on photodiodes are used.
- Measurements are taken by passing x-rays through out the body. Many data scans are taken progressively from the body and they are combined together by a mathematical procedures know as tomographic reconstruction.
- The mathematical procedure is called back projection reconstruction. By using reconstruction methods we can reconstruct the image

IMAGE RECONSTRUCTION

9.4.5 Mathematical Basis of Image Construction

CT scan is obtained from more than 1000 images obtained through X-ray imaging. The mathematical basis for CT scan is that if one measures the total attenuation along rows and columns of a matrix then one can compute the attenuation of the matrix elements at the intersection of rows and columns. The number of mathematical operations is large and hence it can be done by a computer. The information obtained by the mathematical operation can be presented in a conventional raster form which is used for display on a television screen or a computer monitor.

A mathematical procedure called back projection reconstruction can illustrate how the attenuation values along the surface of the transverse slice can be computed from the externally measured attenuation factors. The manipulation involves a multidimensional matrix manipulation. To demonstrate easily, a two by two matrix is considered as an example.

STEP 1: Let A be a two by two matrix representing the actual attenuation values normalized to zero. Let us further assume that each number in the matrix represents attenuation of X-ray by the internal structures of the body. The zero is the minimum attenuation (normalized to zero) of the internal structure of the body.

$$A = \begin{bmatrix} 5 & 0 \\ 1 & 3 \end{bmatrix}$$

STEP 2: The first estimate is the attenuation values obtained along the rows, giving a sum of 5 and 4.

Therefore, the first estimate along rows $= \begin{bmatrix} 5 & 5 \\ 4 & 4 \end{bmatrix}$

STEP 3: The second estimate is obtained from the values obtained along the columns, giving a sum of 6 and 3.

Hence, attenuation along column $= \begin{bmatrix} 6 & 3 \\ 6 & 3 \end{bmatrix}$

Second estimate $= \begin{bmatrix} 5 & 5 \\ 4 & 4 \end{bmatrix} + \begin{bmatrix} 6 & 3 \\ 6 & 3 \end{bmatrix} = \begin{bmatrix} 11 & 8 \\ 10 & 7 \end{bmatrix}$

STEP 4: The third estimate is obtained from the values measured along the North-East direction giving the values as follows:

Attenuation along N-E $= \begin{bmatrix} 5 & 1 \\ 1 & 3 \end{bmatrix}$

Third estimate $= \begin{bmatrix} 11 & 8 \\ 10 & 7 \end{bmatrix} + \begin{bmatrix} 5 & 1 \\ 1 & 3 \end{bmatrix} = \begin{bmatrix} 16 & 9 \\ 11 & 10 \end{bmatrix}$

Step 5: The fourth estimate is obtained from the values measured along the North-West direction giving the values as follows:

$$\text{Attenuation along N-W} = \begin{bmatrix} 8 & 0 \\ 1 & 8 \end{bmatrix}$$

$$\text{Fourth estimate} = \begin{bmatrix} 16 & 9 \\ 11 & 10 \end{bmatrix} + \begin{bmatrix} 8 & 0 \\ 1 & 8 \end{bmatrix} = \begin{bmatrix} 24 & 9 \\ 12 & 18 \end{bmatrix}$$

Step 6: Normalize the estimate by subtracting 9 from each element.

$$\text{Normalized estimate is } \begin{bmatrix} 15 & 0 \\ 3 & 9 \end{bmatrix}$$

After normalization, the final image is obtained by dividing each element by 3.

$$\text{That is, } A' = \begin{bmatrix} 5 & 0 \\ 1 & 3 \end{bmatrix}$$

The estimated matrix A' is the same as the given matrix A. Let the numbers in the matrix corresponds to the attenuation of locations on a tissue slice having the same relationship as the matrix numbers. In the sample calculation, the estimation is stopped at the fourth estimate. In the tomography, thousands of estimations will be done and the matrix elements are the corresponding attenuation factors obtained in each X-ray exposure at a particular angle.

DETAILED BLOCK DIAGRAM OF CT SCAN

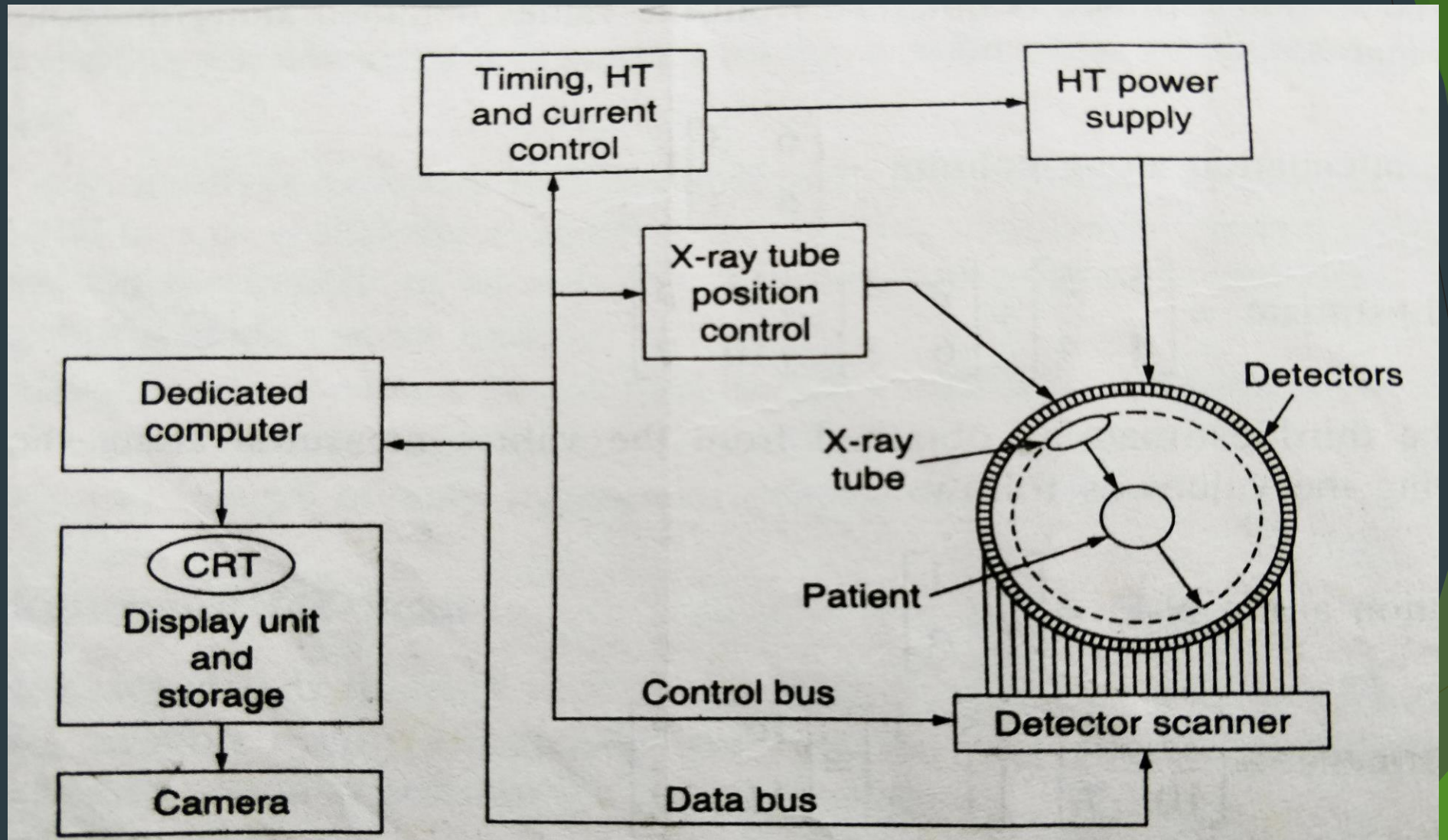

Figure 9.10(a) Block diagram of a CT scanner.

- A typical CT scan machine is shown in above figure
- X-ray source:

The x-ray tube generates the x-ray and direct towards the subject. The x-ray tube is fitted on a circumference of a gantry so that the image can be obtained in all 360 degrees. The person will be placed inside the gantry. A set of x-ray detectors is placed exactly opposite to the X-ray tube.

The radiation dose for a particular study depends on many factors such as volume scanned, number and type of scan sequences, the desired resolution of image and the image quality. The intensity of x-ray can be regulated by controlling the anode voltage and beam current. The timing, anode voltage (in kV) and beam current (in mA) are controlled by a computer through a control bus.

- X-ray Detector:

The x-ray detectors are placed in a ring shaped apparatus which rotate around the patient. The detectors sense the intensity of x-ray as a function of absorption property of the internal structure of body.

Detection should be done by scintillation system based on photo detectors. Detection which utilizes 8,16 or 64 detectors during continuous motion of patient through the radiation beam to obtain much clearer images with high resolution and image quality.

- Reconstruction of tomogram:

The CT produces a group of data which can be manipulated and processes to demonstrate various bodily structures based on their ability to block the x-ray beam. It is called windowing technique. The reconstruction of tomogram is done using a suitable computational algorithm using a computer.

By using a computer the image can be produced in a television screen. This is called tomogram and it can provide a very accurate cross sectional view of any area of the body. To reconstruct the image a number of mathematical operations has to be done and for this we use different computational tools.

Back projection is a simplest tomographic reconstruction method. Modern software allows reconstruction of the tomograms in many planes so that any plane can be selected to display an anatomical structure. This may be useful for visualising the structure of extremely small elements of body such as bronchi.

9.4.3 Advantages and Disadvantages of CT Scan

Advantages

1. CT scan offers detailed views of tissues like lungs, bones, soft tissues and blood vessels.
2. CT scan is painless, noninvasive and accurate.
3. CT scan is quick and simple. In trauma cases, it can reveal internal injuries and bleeding quickly so as to save lives.
4. Diagnosis with the help of CT scan has the potential to eliminate the need for invasive exploratory surgery and surgical biopsy.
5. CT scan can distinguish between normal and abnormal structures. It is a useful tool to guide radiotherapy, needle biopsies and all minimally invasive procedures.
6. CT scan is a cost-effective imaging tool for a wide range of clinical problems.

Disadvantages

1. CT scan involves exposure to X-ray radiation. The radiation dose from this procedure is equal to a dose that the average person receives from background radiation in three years, but the benefit of an accurate diagnosis far outweighs the risk.
2. Pregnant women cannot undergo CT scan.
3. Lactating mothers cannot breast feed for 24 hours after contrast injection.
4. The contrast material injected may lead to allergic reaction.
5. This gives images of only transverse sections of the body.

9.4.4 Limitations of CT Scan

Very fine soft-tissue details in areas such as the knee or shoulder may not be revealed using CT scan. It can be more readily and clearly seen with the magnetic resonance imaging (MRI). The CT scan is not generally suitable for pregnant women.

MAJOR APPLICATION OF CT SCAN

major applications of the CT scan:

1. To investigate multiple organ injury due to trauma and accidents
2. To confirm the presence of cysts, solid tumours in various parts of the body
3. To know the size and extent of damage of organs as a result of the lesions
4. To investigate problems related to the spinal cord such as osteoporosis
5. To diagnose the sudden abdominal pain, blood in the urine, and renal infection
6. To ensure presence of tumour and to determine the stage of a tumour
7. To identify stones in the urinary bladder
8. To plan radiation treatments for tumours
9. To guide biopsy needle and to guide minimally invasive procedures
10. To detect small bone injuries
11. To locate the bleeding and damage in the brain