Name of the Course: EIBX01
Biomedical Instrumentation Module - 5

COMPUTER TOMOGRAPHY (CT)

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Computer tomography

- It is a new method of forming images from x-rays
- It was developed and introduced by Godfrey Hounsfield (Nobel prize – 1979)
- Also referred to as computerized axial tomography or computer transmission tomography or computer tomography

COMPUTER TOMOGRAPHY (CT)

INTRODUCTION:

A new method of forming images from X-rays was developed and introduced into clinical use by British Physicist Godfrey Hounsfield and is referred as computerised Axial tomography or computer tomography.

PRINCIPLE:

- ✓ Measurements are taken from the transmitted X-rays through the body and contain information on all the constituents of the body in the path of the X-ray beam.
- ✓ By using multidirectional scanning of the object, multiple data are calculated.
- ✓ The mathematical basis for producing an image of the cross section of these bodies is that if one measures the total attenuation along rows and columns of a matrix, one can compute that attenuation of the matrix elements at the intersections of the rows and columns.

✓The number of mathematical operations necessary to yield clinically applicable and accurate images is so large that a computer is essential to do them.

✓Computer performs the calculations and obtains an information.

✓This information can be presented in a conventional raster form and from these results a 2 D picture (slice) can be obtained..

Basic Principle

- Internal structure of an object can be reconstructed from multiple projections of the object.
- Pencil like or fan shaped x-ray beam is used
- Source and detector move around synchronously around the slice of interest
- Transmitted radiation counted by a scintillation detector
- Computer analysis by mathematical algorithm and reconstruction of images

Mathematical Basis of Image Construction

- Done using a method called BACK PROJECTION RECONSTRUCTION
- Illustrates how the attenuation value along the surface of a transverse slice can be computed from the externally measured attenuation process
- For simplicity a simple 2X2 matrix is taken into account

STEP 1:

Suppose the actual attenuation values, normalised to zero, are represented by a 2 x 2 matrix,

$$\begin{pmatrix} 2 & 0 \\ 1 & 3 \end{pmatrix}$$

Each number in the matrix represents the attenuation of the space where it is located.

Here “0” is a measure of the attenuation in the upper right hand corner of the matrix

STEP 2 (first estimate)

The attenuation values are measured from the outside as those seen along the rows giving the sums 2 and 4. using these as the first estimate we have attenuation numbers,

$$\begin{matrix}\rightarrow \\ \rightarrow\end{matrix}\begin{bmatrix} 2 & 0 \\ 1 & 3 \end{bmatrix}\begin{matrix}\leftarrow \\ \leftarrow\end{matrix} \Leftrightarrow \begin{bmatrix} 2 & 2 \\ 4 & 4 \end{bmatrix}$$

STEP 3 (second estimate)

The second estimate is obtained from the values measured along the columns giving the sums 3 and 3. Thus we have

$$\begin{matrix}\downarrow & \downarrow\\ 2 & 0\\ 1 & 3\\ \uparrow & \uparrow\end{matrix} \Longleftrightarrow \begin{pmatrix}3 & 3\\ 3 & 3\end{pmatrix}$$

Now add this matrix to the first estimate to get the second estimate as

$$\begin{bmatrix} 2 & 2 \\ 4 & 4 \end{bmatrix} + \begin{bmatrix} 3 & 3 \\ 3 & 3 \end{bmatrix} = \begin{bmatrix} 5 & 5 \\ 7 & 7 \end{bmatrix}$$

STEP 4 (third estimate)

A third estimate can be obtained from the values measured along the north east diagonal giving the following matrix:

$$\begin{bmatrix} \mathbf{2} & \mathbf{1} \\ \mathbf{1} & \mathbf{3} \end{bmatrix}$$

Add this to the second estimate to get the third estimate as

$$\begin{pmatrix} 5 & 5 \\ 7 & 7 \end{pmatrix} + \begin{pmatrix} 2 & 1 \\ 1 & 3 \end{pmatrix} = \begin{pmatrix} 7 & 6 \\ 8 & 10 \end{pmatrix}$$

STEP 5 (fourth estimate)

A fourth estimate can be obtained from the values measured along the north west diagonal giving the following matrix:

$$\begin{pmatrix} \mathbf{5} & \mathbf{0} \\ \mathbf{1} & \mathbf{5} \end{pmatrix}$$

Add this to the second estimate to get the third estimate as

$$\begin{pmatrix} 7 & 6 \\ 8 & 10 \end{pmatrix} + \begin{pmatrix} 5 & 0 \\ 1 & 5 \end{pmatrix} = \begin{pmatrix} 12 & 6 \\ 9 & 15 \end{pmatrix}$$

STEP 6 (final image)

Normalize the fourth estimate to zero by subtracting 6 from each element:

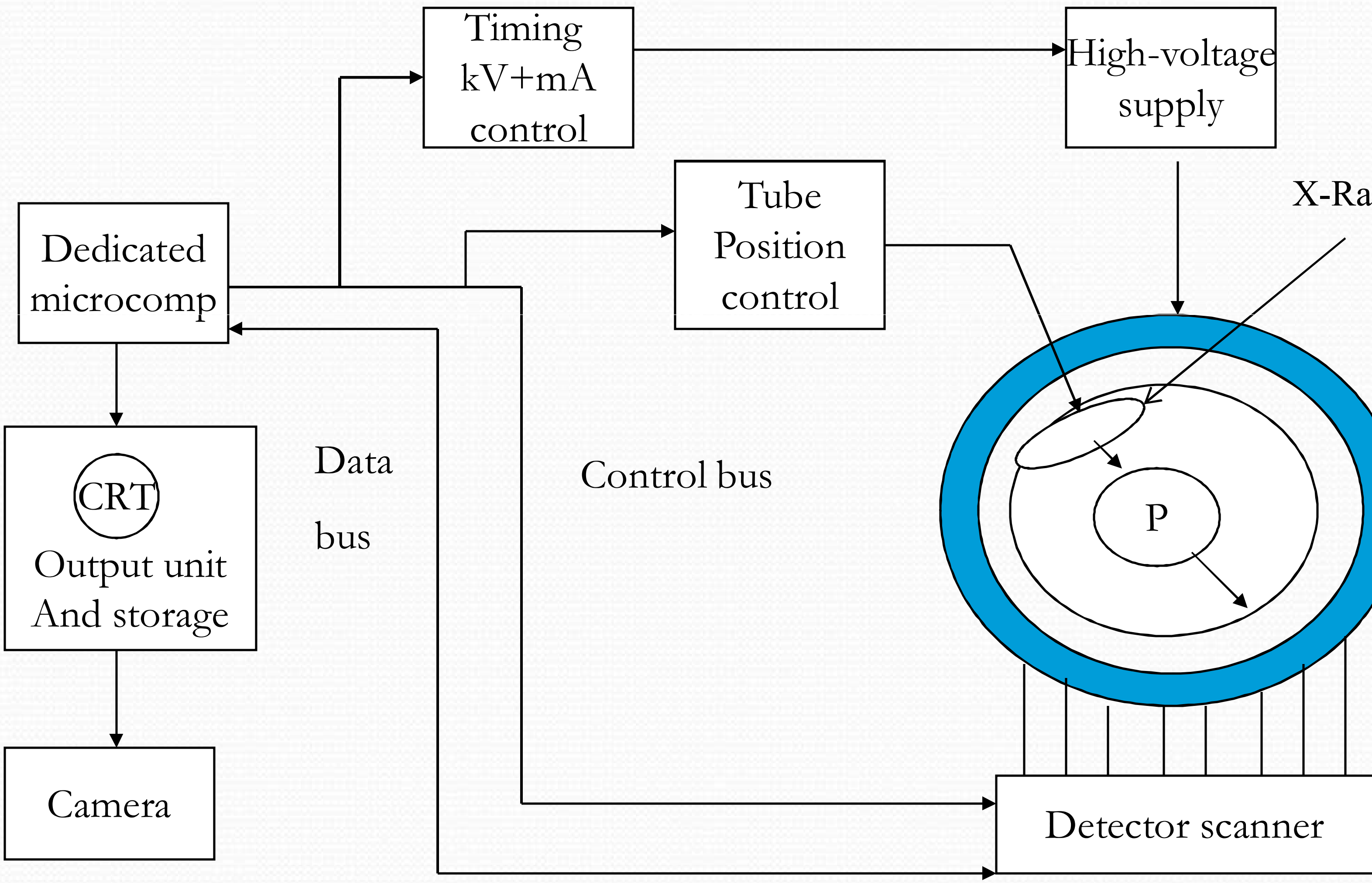
$$\begin{pmatrix} \mathbf{6} & \mathbf{0} \\ \mathbf{3} & \mathbf{9} \end{pmatrix}$$

Then divide this by 3 to yield final image

$$\begin{pmatrix} 2 & 0 \\ \\ 1 & 3 \end{pmatrix}$$

- The final matrix is the same as the first one.
- The numbers in the matrix correspond to the attenuations of locations on a tissue slice having the same spatial relationship as the matrix numbers.
- It is seen that the final image has the same attenuation values as the actual transverse slice but the values are obtained from external measurements of attenuation along using CT.
- The computer does similar calculation in a large scale and finds the matrix values

BLOCK DIAGRAM FOR A COMPUTER TOMOGRAPHY SCANNER



- The timing, anode voltage (kV) and beam current (mA) are controlled by a computer through a control bus.
- The high voltage d.c power supply drives an X-ray tube that can be mechanically rotated along the circumference of a gantry.
- The patient is lying in a tube through the centre of the gantry.
- The X-rays pass through the patient and are partially absorbed and the remaining X-ray photons impinge upon several of as many as 1000 radiation detectors fixed around the circumference of the gantry.

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- The detector response is directly related to the number of photons impinging on it and so to tissue density since a greater proportion of X-rays passing through the dense tissues are absorbed than that are absorbed by the less dense tissues.
- When they strike the detector, the X-ray photons are converted to scintillations.
- The computer sense the position of the X-ray tube and samples the output of the detector along a diameter line opposite to the X-ray tube.

- A calculation based on data obtained from a complete scan is made by the computer.
- The output unit then produces a visual image of the transverse plane cross-section of the patient on the cathode ray tube.
- It can also be photographed with a camera to produce a hard copy record.
- The present day CT machines can obtain slices in 1-2 seconds in high resolution and 5-10 seconds in precision modes.

APPLICATIONS OF CT

CENTRAL NERVOUS SYSTEM:

CT has replaced the diagnostic techniques like cisternography and ventriculography. CT stereotaxy is another innovation for diagnostic and therapeutic procedures in brain without open surgery.

Injuries

It detects small bone injuries, the presence or absence, location and extent of bleeding and damge to the brain and ventricular system.

Vascular Lesions:

CT scan is immensely helpful in detecting arteriovenous malformations like angiomas and aneurysms before catastrophic bleeding occurs due to its rupture. Hemorrhage inside brain of non-traumatic causes, cerebral thrombosis are emergencies requiring CT imaging.

In Oncology:

CT is an accepted first line investigation for primary malignant lesions, differential diagnosis with other benign lesions and for detecting metastatic disease where surgical removal of solitary metastasis is made feasible.

In Degenerative disease:

Degenerative diseases like cerebral atrophy, helminthic infestations of brain and chronic inflammatory diseases like tuberculomas can be detected using CT scans.

ORTHOPEDICS AND BONE TUMOURS:

CT scan is used for designing custom made prosthesis for limb conserving or preserving surgery both in bone tumors and in traumatic fractures.

➢ Assessing the lesion with reference to various components (medulla, cortex, soft tissue compartment).

➢ Dimensions of bone for resection and for making prosthesis. The assessment of whether patient is suitable for prosthesis or not depends mainly on CT imaging.

Thorax:

➢ In the screening of high risk group (chronic smokers) for early detection of lung cancer.

➢ In differential diagnosis of solitary pulmonary noduly whether it is malignant or non-malignant.

THANK YOU