Technology Brief 6: X-Ray Computed Tomography

Tomography is derived from the Greek words *tome* (meaning section or slice) and *graphia* (meaning writing). Computed tomography, also known as ***CT scan*** or ***CAT scan*** (for computed axial tomography), refers to a technique capable of generating 3-D images of X-ray attenuation (absorption) properties of an object. This is in contrast to the traditional, X-ray technique that produces only a 2-D profile of the object (Fig. T6-1). CT was invented in 1972 by British electrical engineer ***Godfrey Hounsfeld*** and independently by ***Allan Cormack***, a South African-born American physicist. The two inventors shared the ***1979 Nobel prize for Physiology or Medicine***. Among diagnostic imaging techniques, CT has the decided advantage in having the sensitivity to image body parts on a wide range of densities, from soft tissue to blood vessels and bones.

Figure TF6-1: 2-D X-ray image. (Courtesy of General Electric.)

Principle of Operation

In the system shown in Fig. T6-2, the X-ray source and detector array are contained inside a circular structure through which the patient is moved along a conveyor belt. A CAT scan technician can monitor the reconstructed images to

insure that they do not contain artifacts such as streaks or blurry sections caused by movement on the part of the patient during the measurement process.

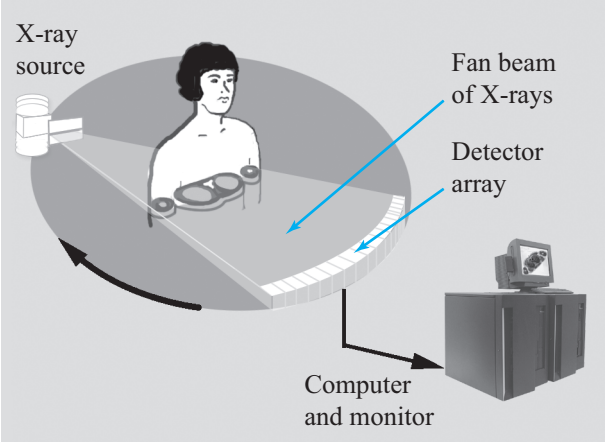
A CT scanner uses an ***X-ray source*** with a narrow slit that generates a ***fan-beam***, wide enough to encompass the extent of the body, but only a few millimeters in thickness [Fig. T6-3(a)]. Instead of recording the attenuated X-ray beam on film, it is captured by an array of some 700 ***detectors***. The X-ray source and the detector array are mounted on a circular frame that rotates in steps of a fraction of a degree over a full 360° circle around the patient, each time recording an X-ray attenuation profile from a different angular perspective. Typically, 1,000 such profiles are recorded per each thin traverse slice of anatomy. In today's technology, this process is completed in less than 1 second. To image an entire part of the body, such as the chest or head, the process is repeated over multiple slices (layers), which typically takes about 10 seconds to complete.

Figure TF6-2: CT scanner.

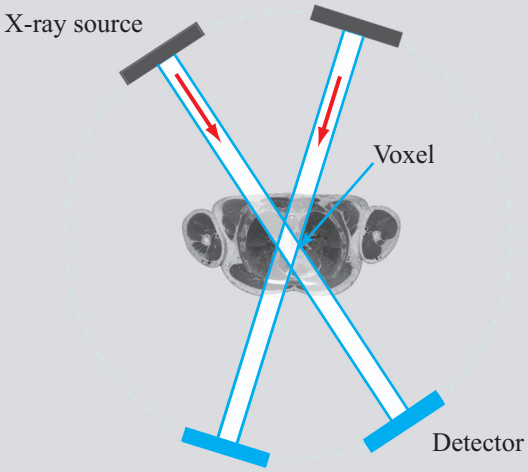
Image Reconstruction

For each anatomical slice, the CT scanner generates on the order of 7×10^5 measurements (1,000 angular orientations $\times 700$ detector channels). Each measurement represents the integrated path attenuation for the narrow beam between the X-ray source and the detector [Fig. T6-3(b)], and each volume element ***(voxel)*** contributes to 1,000 such

measurement beams. Commercial CT machines use a technique called ***filtered back-projection*** to "reconstruct" an image of the attenuation rate of each voxel in the anatomical slice and, by extension, for each voxel in the entire body organ. This is accomplished through the application of a sophisticated matrix inversion process. A sample CT image of the brain is shown in Fig. T6-3(c).



(a) CT scanner



(b) Detector measures integrated attenuation along anatomical path

(c) CT image of a normal brain

Figure TF6-3: Basic elements of a CT scanner.