Technical Concepts of X-ray Computed Tomography Scanners

Medical examinations using computed tomography are currently standard hospital practice. Back in the 1980s, its use was relatively rare, and was available only in a limited number of specialised medical centres. Today it is hard to imagine medical diagnosis without it.

Nowadays, hospitals in most major cities are equipped with CT devices. They are deployed, taking into account the prevailing demographic situation, so that optimal use is made of the equipment and the time needed for a patient to reach a centre is minimized. Computed tomography is used in the diagnosis of many conditions, both chronic and acute.

The installation of a CT scanner requires complex preparatory work. For a medical centre to be able to carry out on-site tomographic examinations, it must first adapt a suite of rooms for the purpose. The CT room must meet several requirements:

• it must have floors with adequate load-carrying capacity,
• its walls must be constructed of X-ray absorbing material (this is usually a barium (Ba) plaster),
• the floor should be lined with material that is both anti-slip and antistatic.

Separate rooms should be provided for the CT scanner and for the radiographers; the rooms must be separated from each other by special window-glass (containing lead, Pb), to protect against X-rays. In addition, a suite of CT rooms must comply with all the health and welfare regulations, which are typically required for units carrying out medical X-ray examinations. A typical CT suite showing the location of the various elements of the scanner is illustrated in Fig. 3.1.

We can consider the CT scanner as being composed of two layers: the computer layer and the physical layer. The computer layer consists of the operating system responsible for running the tomography application, file management and
communication with external devices; and the tomography application itself. The latter

has two basic functions: user and utility. The user function carries out the tasks associated with the preparation of the scanner for operation, the management of the scanning process itself, the acquisition of the projection data, image reconstruction, support functions aiding diagnosis from the reconstructed images and archiving of the tomographic images. The utility function deals with the technical parameters of the scanner, the diagnosis of errors and other service tasks.

A CT scanner consists of the following main elements

• a data acquisition system that carries out the X-ray projections,
• a computer to reconstruct the images from the projections and to assist in the analysis of the reconstructed images,
• a variable power supply,
• a monitor to display the routine operation of the computer system and to act as an interactive interface in the diagnosis of the reconstructed images,
• a documentation camera to produce an image on film similar to traditional X-ray
images,
• other data archiving systems, such as tape or disk, collectively referred to as storage devices,
• other elements.
As can be seen from Fig. 3.1, the scanner itself is situated behind a screen to protect the operators from the harmful effects of the X-rays emitted by the tube. The other components of the CT system are located in the same room as the technicians and doctors.

1 Data Acquisition Systems
Whatever the differences in design of the different generations of scanners, the main elements remain the same. Figure 3.2 presents three orthogonal views of a standard design of data acquisition system. Some elements of the apparatus shown in Fig. 3.2 are immediately recognisable, while others are part of the larger units and are not visible.
The main components of the scanner design are:

- The gantry with a central opening, into which the patient is moved during the examination. This is the most recognisable element of the CT scanner;
• The X-ray tube, the source of the X-rays that pass through the body situated in the gantry and carry the information about the structure of the body to the detectors. The information is in the form of a series of projections;
• The detector array converts the projection values, in the form of radiation intensities, into electrical quantities. Usually, the whole detector array rotates synchronously with the X-ray tube around the test object;
• The table allows the patient to be manoeuvred easily into position. The table can be controlled manually before the actual scan begins, but it moves automatically during the scan. The table can be moved into or out of the gantry along the axis of the patient’s body, as well as up and down. This allows the patient to be appropriately positioned depending on which part of the body is being examined. 

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positioned depending on which part of the body is being examined.

The scanner also contains a number of sub-systems that drive and control the device, enable precise positioning of the patient during the scan as well as facilitate communication with the patient.

The evolution of CT scanners has been marked by changes to the design of the projection sub-systems of the data acquisition system [2, 3, 18]. In comparing these designs, only those that represent commonly used classes of CT devices are listed below; non-typical or prototype designs have been omitted.

The design of each of the CT scanner generations contains one of three basic tube-detector projection systems

• a projection system using a parallel beam of radiation (a parallel-beam system),

• a system using a beam of radiation in the shape of a fan (a fan-beam system),

• a system using a beam of radiation in the shape of a cone (a cone-beam system).