Integrating Computers into imaging: Digital Radiography (DR)

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Objectives: Upon completion of this CME article, the reader will be able to:

1. Define basic computer terminology of the Windows operating system

2. List the operational/application components of a digital image

3. Describe the process of digital image acquisition

4. Explain the effect of resolution, exposure, and image quality

Introduction

The intent of this article is to introduce the reader to the application of digitalization within an imaging department. Digital Radiography is a broad term commonly used to describe the production of images in a computer-based radiology department. The term, Digital Imaging, is probably a more accurate term because ionizing radiation is not only energy used within a radiology department. A variety of other energies are utilized in acquiring an image, including sound, light, magnetic, and radio wave.

Clinical use of digital imaging requires the integration of various computer applications. Regardless of the energy source, computer processing creates the manifest (or visible) image in a digital format.

Digitalization

The space program was the first to use digitalization of images that were sent from space. Diagnostic imaging departments today our second only to the space program in utilizing digital information data. Digital information generated in an imaging department is the basis for Computed Radiography (CR), Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Nuclear Medicine (NM), and Digital Fluoroscopy (DF).

Although the image generated in digital imaging may be imprinted on photographic film, it is considered digital because of the process used in converting the conventional method into digital format. In short, the conventional method or conventional radiography is one that produces an analog image. Analog images can be created by drawing, painting, or by the photoelectric effect, whereas digitalization is the method of converting the analog data into digital data by means of computer applications and processing.

Digital Radiography

The term digital radiography should be used to specify images that are acquired through the use of an ionizing radiation absorption detector or a charged- coupled device system. Detectors that absorb x-ray energy and convert the energy to light energy are usually designed on a flat panel or thin-film

transistor (TFT) installed in the radiography equipment or unit. These detectors are capable of responding with speed and consistency and are highly sensitive and stable. Detectors are designed to have high capture efficiency. This is controlled by the size of the detectors as well as the distance between each detector. Detectors must also have high absorption efficiency. This is controlled by the size and thickness of the detector, as well as the type of material used. Thus, detectors are able to absorb ionizing radiation and convert this energy into light.

On the other hand, a charge-coupled device (CCD) stores charges from light that is exposed to a photosensitive surface. This stored electron charge is the latent (or invisible) image. The CCD releases this charge upon being scanned and discharged into a conductor. There is no lag time due to the immediate discharge.

There are two categories of digital conversion in digital radiography:

- Indirect Capture
- Direct Capture

With indirect capture, the discharged light is converted into electrical signals with an analog to digital converter (ADC) that is processed through the computer. Direct capture uses a photoconductor that absorbs and sends converted at-ray energy directly to the computer as electrical signals.

Digital computers
A dedicated digital computer is required for processing digital images. Digital computers contained a computer chip. This chip reads all direct input electrical signals and assigns discrete numbers. They have what is called distinguished functionality. Digital computers apply both arithmetic and logic functions (in order to create higher sequencing, computations, and order).
The basis of a digital computer is the binary number system. The binary number system uses a base of 2. The numerical values are represented by 0 and 1; for example, the number 9 in the decimal system is 1001 in the binary system:
- $(1 \times 8) + (0 \times 4) + (0 \times 2) + (1 \times 1) = 9$
Binary numbers and become very long so other number systems may be used, which might include:
- Octal system with a base = 8 (numbers 0-7 are used)
- Hexadecimal system with a base = 16 (numbers 0-9 are used plus the 1st six letters of the alphabet)
Input data represents certain colds using the binary number system such as4-bit code, 6-bit code and 8-bit code (the 8-bit code is called a BYTE). The primary mathematical method used in the creation of images is an algorithm. The continuous Fourier transform is one of the specific forms in mathematics that represents the process/formula that transforms one function into another. This application permits the reconstruction of portions of the data in other portions, and their relationships are known and vice versa.
In computers, the kernel is the main operating system software that allows access to the hardware and all application software must go through the kernel in order to access the hardware. All

hardware drivers (like printer drivers, etc.) are actually installed into the kernel, and the kernel controls those drivers. The primary purpose of the kernel is to manage the computer's resources, allowing other programs to run. One of the resources the kernel manages is the Central Processing Unit (CPU). The CPU is the most central part of a computer system and is responsible for running or executing programs.

Digital signal processing occurs for each signal (or energy wave) that has been transformed mathematically into digital format. The algorithms required for digital signal processing are performed using dedicated digital computers that make use of specialized microprocessors. Conversion of the signal from an analog to digital form utilizes microprocessors called analog to digital converters (ADC) or digital signal processors (DSP).

DSP's are specifically designed to handle volumes of information quickly and efficiently. They must capture, store, and retrieve large volumes of data and also be able to manipulate the data upon user command.

Peripherals

High-resolution monitors and printing systems should be used when displaying digital images. The final reconstructed image is most often displayed on a Cathode Ray Tube TV monitor or a Liquid Crystal Display flat-screen device. The display device is interfaced with the digital radiography unit and makes called a workstation, user terminal, operator's console, and/or remote workstation. Depending on the system specification, the workstation may have the same capabilities or functions as an operator's console. However, the operator's console is usually the only display device that can control the image's post-processing features. Digital radiographic images are reconstructed each time from the primary data. The visible image quality is directly related to the display device.

Although the Cathode Ray Tube (CRT) is still the most commonly used display device in imaging departments, the Liquid Crystal Display (LCD) is quickly increasing, and supply and demand. It is predicted that in the use of, CRT screens will disappear from the most department, especially said many large manufacturers no longer produce the CRT computer display. LCD panels can produce sharper images. They have more vibrant images with excellent contrast capability (meaning the boundaries of structures of different composition can be clearly delineated).

Digital Image Reconstruction

A digital image is displayed as a series of minute picture elements called *pixels*. The pixels are arranged in vertical columns in horizontal rows, and this is called the *matrix*. The number of pixels in the image determines the matrix size. The higher the number of pixels in the matrix display, the higher the image quality or spatial resolution. Spatial resolution is defined as the ability of an image to display items that are separate but are closely together. The digital image is still displayed in "grayscale" format (white and gray to black). Digital software programs assign individual pixels and

different grayscale levels of brightness based on the attenuation value of the imaged tissues. Attenuation refers to the absorption of the x-ray beam, and absorption is influenced by the density, atomic number, and thickness of the tissue, as well as, the energy of the x-ray beam or volume element (*voxel*).

Digital imaging has an advantage over conventional imaging in that the grayscale values of the pixels can be manipulated. The number of grayscale values that can be assigned to a pixel is a function of the computer's capability to process digital information. This ability is directly related to the core values of the analog to digital converter (ADC). Most modern digital computers use 10 to 12 bit ADC's. A 10-bit ADC allows for up to 1024 shades of gray, while a 12-bit ADC permits up to 4096 shades of gray for each pixel. The operator has the ability to enhance the image characteristics through the adjustment of the grayscale after the image has been acquired. This is accomplished by adjusting operating functions while in the active window using the *window level* and the *window width* controls.

The window level controls during different tissues into the visible range based on their attenuation values. The 'window level' represents the digital density or brightness of the obtained image. The midpoint of the displayed grayscale is referred to as the center and represents the average brightness. Adjusting the window level (or center) equally changes all of the densities displayed. Images can be manipulated to specifically visualize anatomical characteristics, such as soft tissue, specific organs, and/or bone detail.

The window width increases the difference in the grayscale values and creates an image that has greater contracts (black versus white). Changing the ratio of the density difference shortens or lengthens the total number of intensities. For example, adjusting the window width to a lower value for a chest image with better demonstrate air-fluid levels within the anatomists while increasing the window width would better demonstrate the soft tissue areas of the lung.

Retrieving the digital image is performed at a dedicated computer that is operating from a Windows-based program. Windows provides a graphical user interface (GUI), allows for multitasking, supports many peripheral devices, and provides virtual memory management. Windows eliminates the need for a user to have to type each command into a command line by using a mouse to navigate through buttons, icons, drop-down menus, and dialog boxes. Digital software packages are usually based upon Windows applications in order to reduce the learning curve for the user.

Terminology

The *desktop* is the primary screen that Windows first appears on. The various symbols that appear on the desktop are called *icons*. Tasks are performed on the computer using different *windows* that are accessed through the use of these icons for life areas menus. The window that is currently displayed on the monitor screen is the *active* window. Thus, the digital imaging application will appear on the

monitor screen as its own window. Digital imaging software has elements in common with most Windows-based programs such as the *title bar* and *menu bar*. The title bar on the active window displays the name of the program or file in use. The menu bar contains the commands that are available for that specific program. These *scroll bar* (usually located on the right and/or bottom of the screen) allows the user to move through the document or list in the active window. An individual can also scroll through the active window by using the wheel that is located on the mouse (if the mouse is so equipped). The *maximize button* (usually located in the upper right-hand corner) in large is the active window to fit the entire screen. The minimize button (usually located next to the maximize button) reduces the active window to either an icon that is listed on the bottom taskbar or a small window on top of the larger desktop. The *mouse pointer* appears on the screen of the active window and allows the user to select various tasks. The mouse pointer symbol can be changed into various shapes, such as an arrow or a hand.

The computer mouse plays an important function in selecting and activating an item in order to carry out a task. The following table defines some of the basic mouse terms and/or techniques:

Term	Description
Point	Move the mouse until the point here points to an icon or tasks to be selected on the screen
Click	Press and release the left mouse button quickly one time
Double-click	Press and release the left mouse button quickly twice
Drag	Press and hold the left mouse button down while moving the mouse

A computer mouse usually has "left" and "right" buttons. A single click of the right button usually reveals a drop-down menu. A single click of the left button selects tasks such as the examination being performed, the image to be retrieved, or other imaging options. Dragging with the left mouse button is used in moving an object into a file or other image processing options. In some applications, dragging with the right mouse button may perform functions like windowing in the image.

Digital Radiography Systems Interface Capabilities

The two basic functions for the user of a DR computer system is selecting an examination to be performed or viewing a patient's images. Most systems divide the program into a *study list screen* and an *image viewer screen*. The study list screen allows for selecting patient studies, and the image viewer screen allows the user to retrieve, view, and manipulate images.

When the study list screen is an active window, it usually includes menu options in a toolbar. The menu and toolbar have shortcuts and injuries common to the study list. One menu option allows the user to select a "new patient" study. When a new study is selected, the patient data (or

demographics) must be entered. Every DR system has its own layout for data entry. For most systems, the technologists must key in (or type) the patient information. Other DR systems are interfaced with a bar code system. Today there is a growing need for manufacturers to design DR systems that are capable of interfacing with radiology information systems.

Radiology information systems allow for imaging departments to enter, store, manipulate, and distribute patient information that is pertinent to admissions to the medical center as well as the imaging procedure to be performed. The radiology information system usually includes scheduling of procedures, patient tracking, reporting of results, and integration with hospital information systems and web-based systems.

The importance of computer networking technology cannot be overemphasized. The advancement and integration have had an impact on managing imaging procedures, reducing healthcare costs, improved image access, report turnaround time, and reduction of lost images and reports. Areas that can be addressed by a complete digital imaging department include:

- Scheduling-when the imaging Department receives an order or physician prescription; the patient's appointment can be scheduled in the radiology information system or hospital information system. This enables the imaging department to allocate timeslots for full utilization of the imaging world. This helps in the scheduling of the necessary staff and can reduce over or understaffing issues.
- Patient tracking-from the onset of the patient's arrival and/or admission process to the discharge or study completion can be recorded. The patient's past, present, and future appointments can be tracked. A provider can view the status of past and present procedures that are completed, canceled, and reported.
- Patient management-the entire patient's process within an imaging department can be managed in the radiology information system, meaning that patient information, images, and reports can be added to or retrieved from electronic medical records, viewed by authorized physicians, and stored (archived).

Integration of DR systems with radiology information systems has improved the overall workflow. It has enhanced customer service, improved employee staffing, reduced interest in patient information or loss information, and approved the tracking of information.

The Menu Screens

Study list screen-the listing in the window is usually divided into columns representing various selections options such as selecting a patient's procedure list already in the database or choosing a study date, or status, etc. The study list may allow the user access to other functions such as sending images, creating a hard copy (film or CD) and acquiring images from other formats.

The image viewer screen-image viewer screen is often a pop-up screen, and it is opened after the study is selected by double-clicking the mouse on the exam from the study list screen. The stored

images will load up can be viewed in a preset default grayscale value. The image viewer screen retains the menu and toolbar but usually has additional features that include a variety of image manipulation tools. Images can be sharpened, flipped, rotated, and zoomed (enlarged) and can also be manipulated by changing window levels and width (as previously discussed). In addition, images can be animated and annotated. Annotation tools can include text, arrows, distance measurements, and other geometric shapes.

Display features

As previously stated, the workstation or user terminal allows for the manipulation of images, whereas a display station may or may not allow the user the specific features. The basic function and possibly the most important tool is the ability to adjust the width and center (as previously described).

The Zoom toolbar button is used in adjusting the image for a closer view. The Zoom tool is usually very sensitive; therefore, slow accurate use of the mouse is recommended. After an image has been zoomed the entire image may not be visible on the screen. A pan tool may be an additional feature that would assist the user in moving the image around to see the various areas not demonstrated in the visible window.

A pop-up window associated with a magnifying toolbar button for greater magnification is another additional feature used in digital image manipulation. The magnifying tool creates a temporary image that is very similar to using a magnifying glass.

To focus on a specific region of interest, a Region of Interest (ROI) toolbar button may be utilized. This feature computer information about the area identified inside of the region of interest (ROI) box. A pop-up screen of the specified information, called a configuration bar, will list the specifics such as width, height, and density of the area of interest.

The invert toolbar button is another interesting feature that allows the user to convert the black and white (positive) pixel data into a negative image appearance (subtraction technique).

Lastly, the amortization of digital images can also be of great benefit. It can be utilized in documenting specific findings, creating teaching files, and employed when dealing with medical-legal issues. Annotation consists of adding text and/or graphical objects (such as arrows or distance items) to an image in order to isolate regions of interest, areas of concern, and pathological conditions.

In conclusion, the application and integration of computer-assisted processing of images have made an enormous impact on healthcare in the areas of diagnosis and treatment. The ability to manipulate the raw data both pre-processing and post-processing have enhanced the visual and resolution

capabilities. In turn, digital radiography has impacted the overall patient care in a diagnostic imaging department. From scheduling patient procedures to the final diagnostic report, the turnaround time of completion has been greatly improved.

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