PACS Fundamentals

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Learning Goals

- To Understand the importance of PACS
- To Understand PACS infrastructure requirement
- Introduction to other clinical information system

Objectives

- Introduction to picture archiving and communication systems (PACS).
- Compare and contrast the various types of PACS display workstations.
- Differentiate between the different types of digital imaging workflow.
- Define system architecture and recognize the three major models.
- Summarize the common functions found on a PACS workstation.
- Describe the situations and users that might use advanced PACS workstation functions.

Key Terms

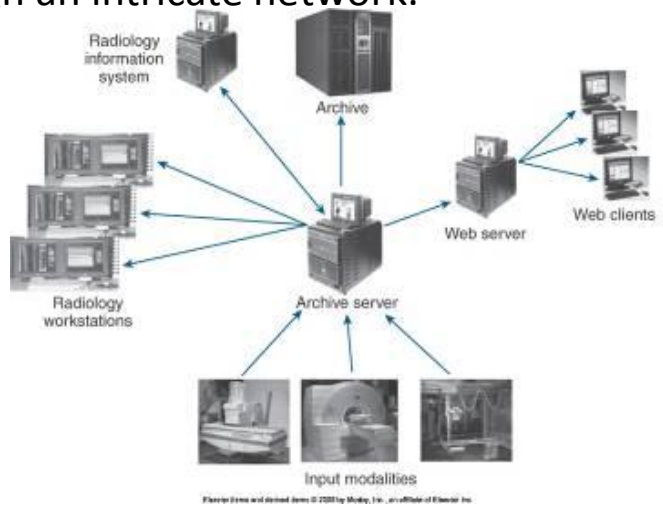
- Archive
- Client/server-based system
- DICOM
- Display workstation
- Distributed system
- File room workstation
- Hanging protocol
- Navigation functions
- PACS
- QC station
- Reading station
- Review station
- Soft copy
- System architecture
- Teleradiology
- Web-based system
- Workflow

Introduction

- PACS
  - Picture
  - Archiving
  - Communication
  - Systems

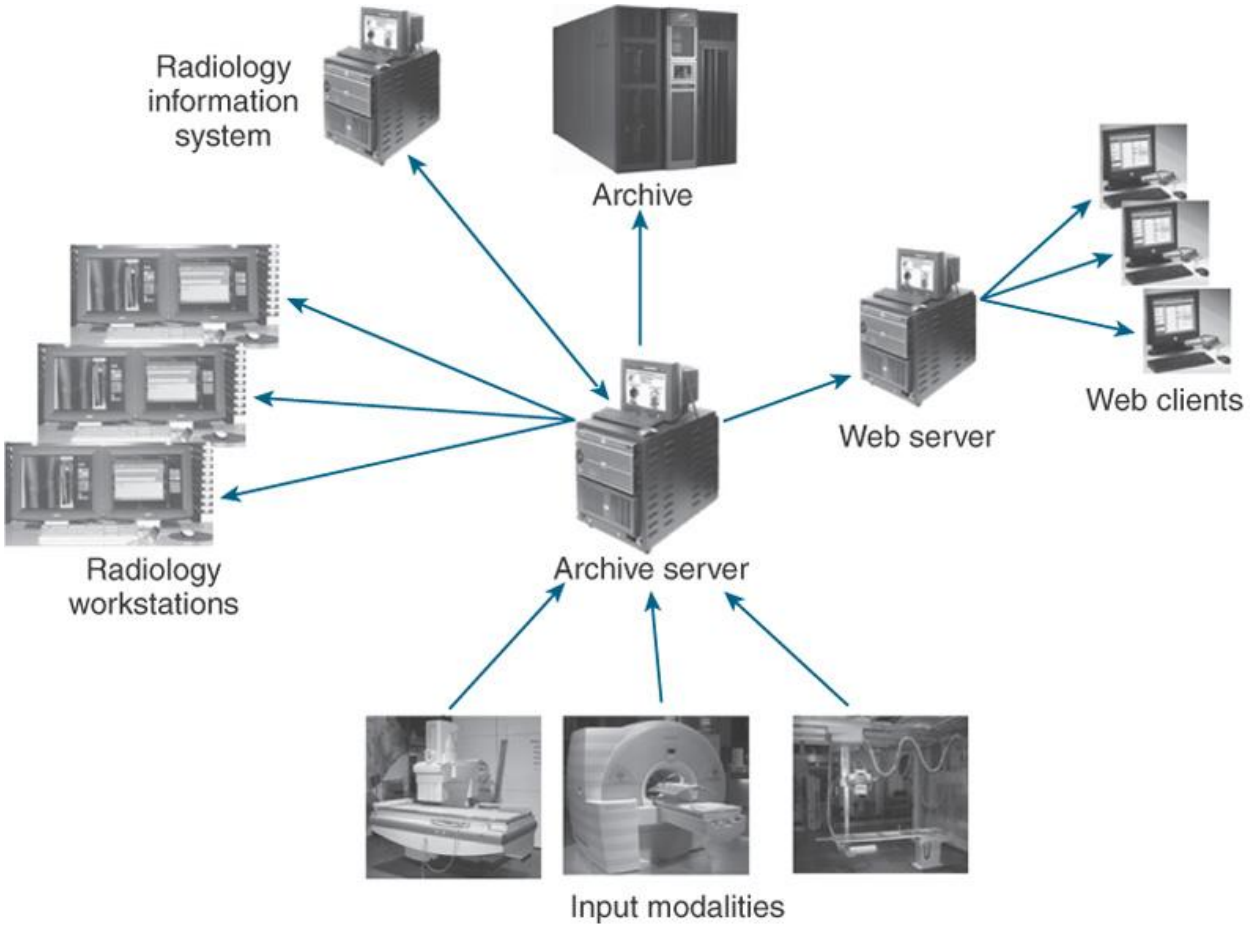
Fundamentals

- PACS consists of the following:
  - Digital acquisition (Picture)
  - Display workstations
  - Storage devices (Archiving)
  - Components are interconnected through an intricate network. (Communication)



- PACS is the electronic version of the radiologist's reading room and the file room.

Typical PACS Design



Fundamentals

- First PACS
  - Early 1980s
  - Served one single modality
  - Large research institutions
  - Most developed by scientists in those institutions
- Later
  - Vendors became more involved.
  - Proprietary systems were developed.
- Standardization

DICOM

- First version was completed in 1985.
- DICOM
  - Digital imaging and communications in medicine.
    - Universally accepted standard
    - Laid the groundwork for the future development of integrated PACSs.
    - Now every modality and PACS communicates via DICOM.
    - Each vendor and modality boasts DICOM compatibility.
- Each DICOM statement must be read carefully to determine the extent of the compatibility.

Components

- PACS can be broken into three fundamental parts:

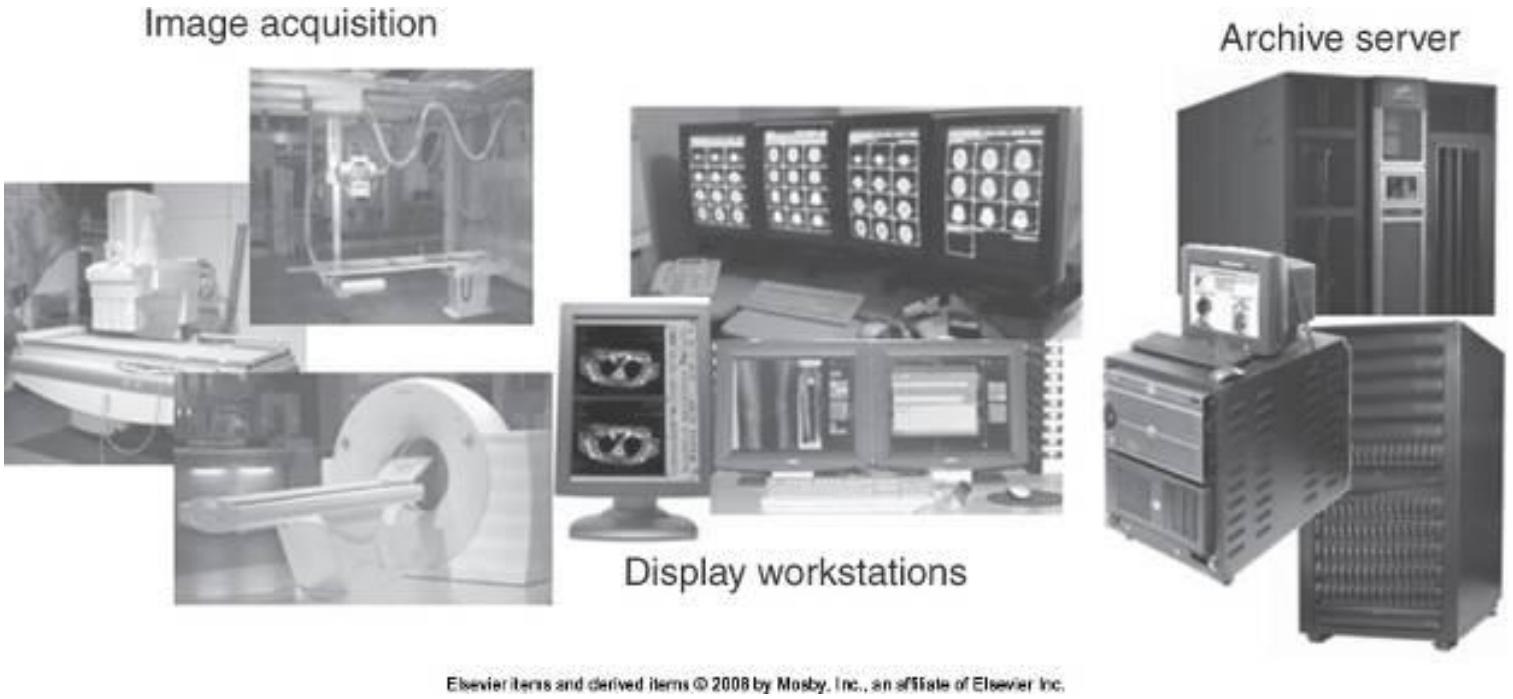


Image Acquisition

- Images are acquired in a digital format:
  - Ultrasound
    - Early ultrasound mini-PACS networks became a norm in many hospitals
  - Computed Tomography (CT)
    - As the images sets increased in number, this necessitated the transition to soft-copy reading
  - Magnetic Resonance Imaging (MRI)
    - As with CT as the numbers of images increased, reading on a monitor became a good alternative.
  - Nuclear medicine
  - Computed radiography
  - Mammography

Display Workstations

- Display workstation is any computer used to view a digital image.

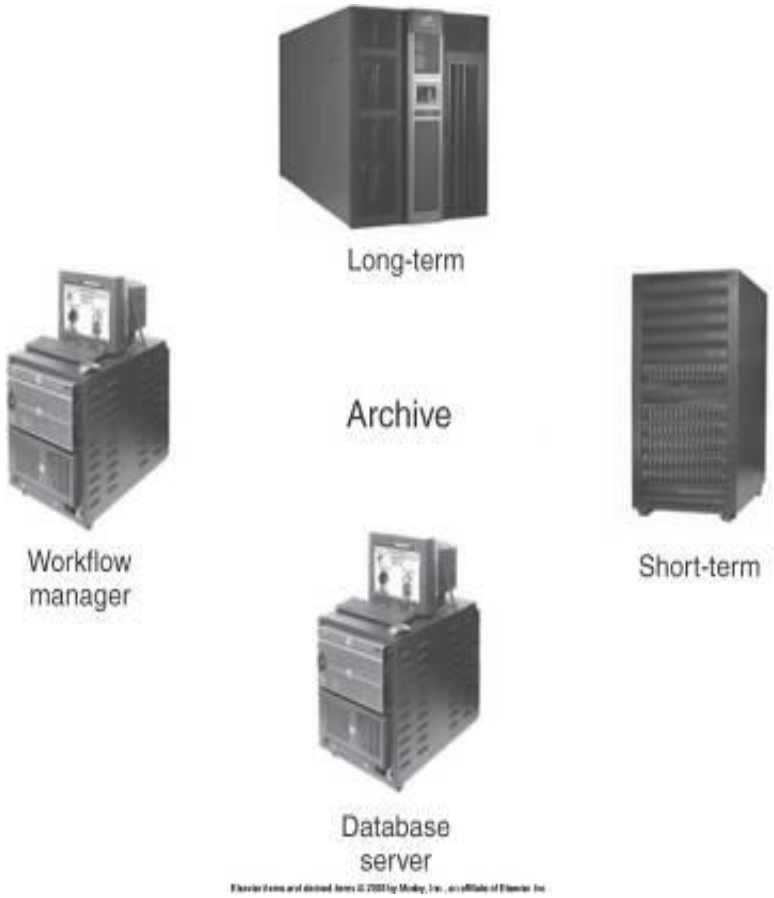
  - Most interactive part of a PACS.
  - Used inside and outside of the radiology department.

Display Workstations

- Display station.
  - Receives images from archive or various radiology modalities
  - Presents images to be viewed
- Workstation has some sort of PACS application software.
- Some may have advanced software with additional image processing capabilities.

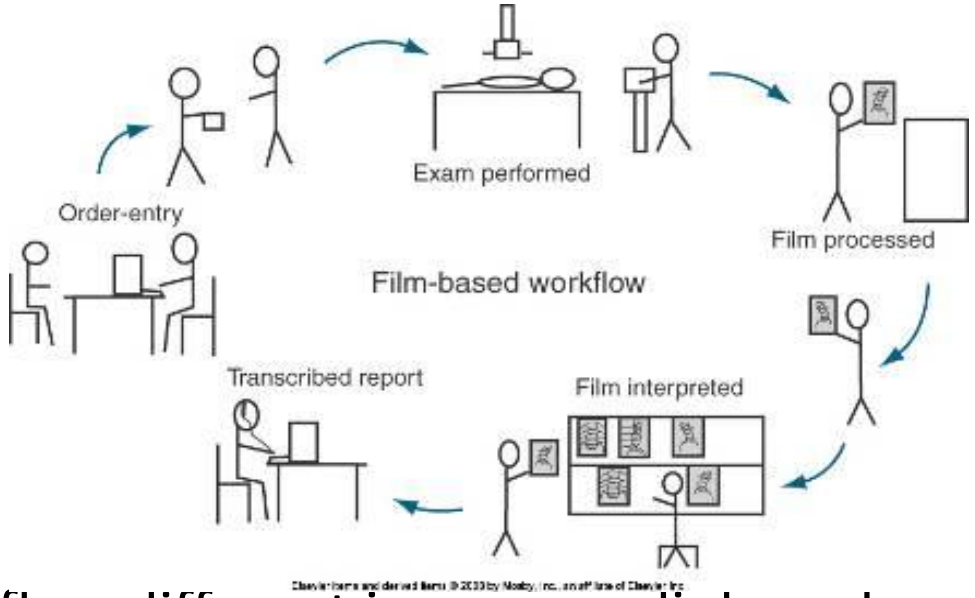
Archive Servers

- File room of the PACS
- Consists of the following:
  - Database server or image manager
  - Short-term and long-term storage
  - Workflow manager
- Central part of the PACS
- Houses all of the historic and current data
- May also serve as the centralized node that receives all images before interpretation



Workflow

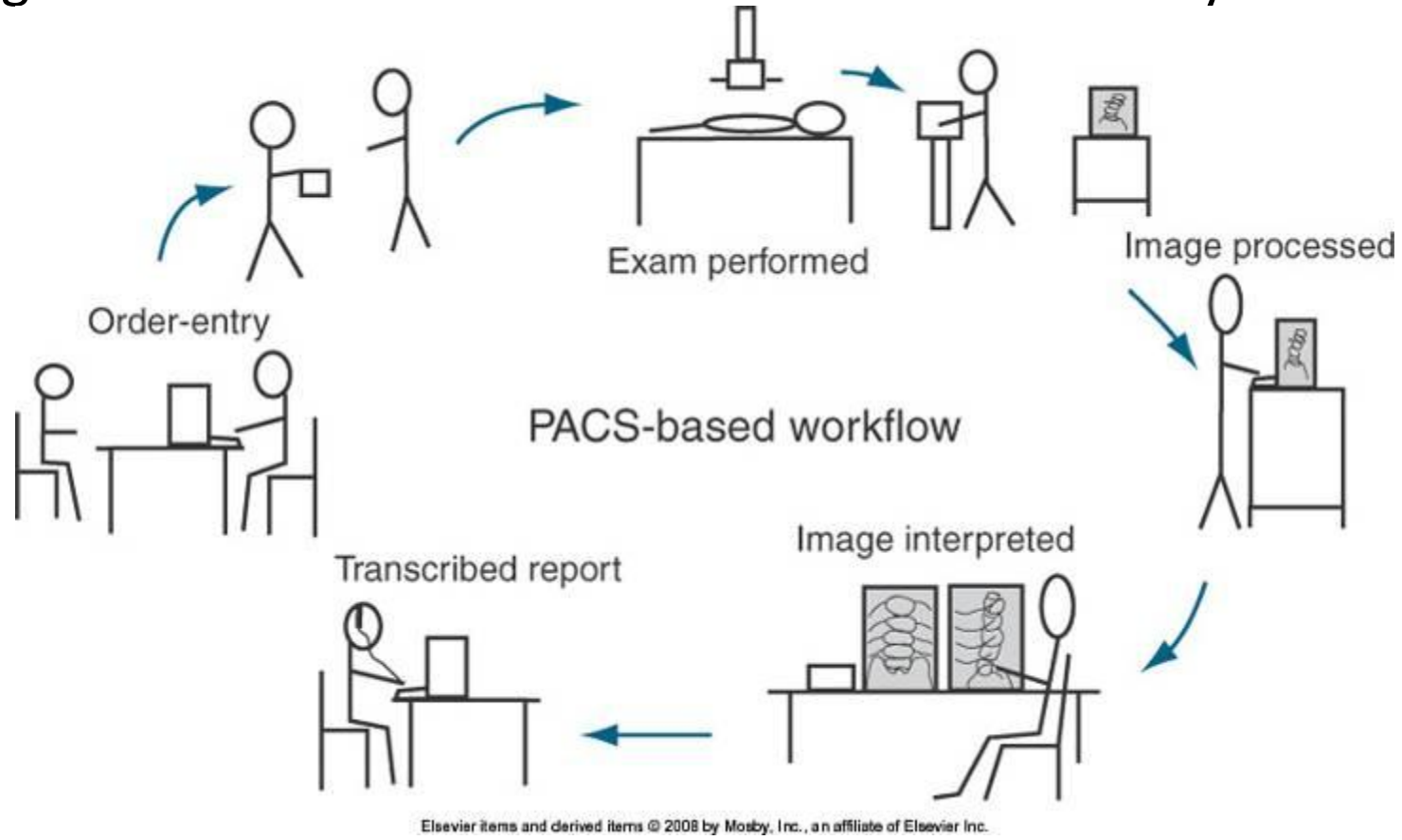
- Workflow
  - How a process is done step by step or how a task is completed
  - How one completes an exam from order entry to transcribed report



- Exact workflow different in every radiology department

Generic Workflow

- Digital is similar but still different from film-based system.



System Architecture

- American National Standards Institute and the Institute of Electrical and Electronics Engineers
  - Definition of system architecture:
    - Basic organization of a system come to life in its components, their associations to each other and the environment, and the principles leading its design and development

System Architecture

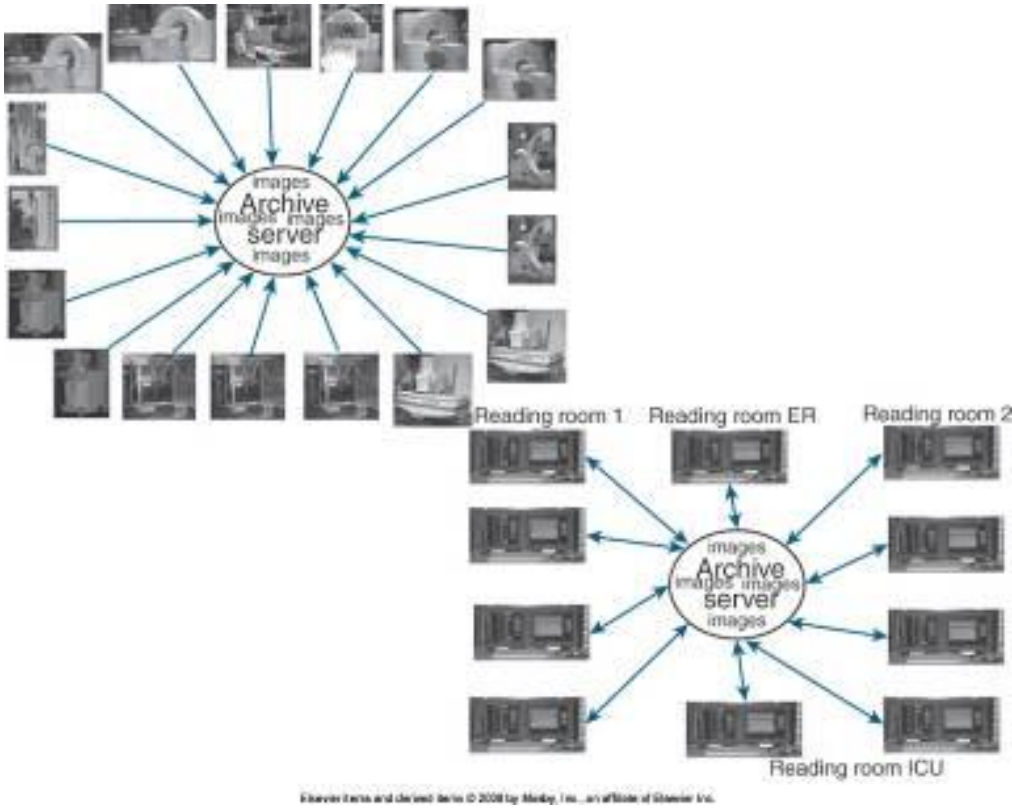
- In other words,
  - System architecture is the hardware and software infrastructure of the systems workflow.
  - In PACS the system architecture normally consists of the following:
    - Acquisition devices
    - Storage and display workstations
    - Image management system

PACS Architecture

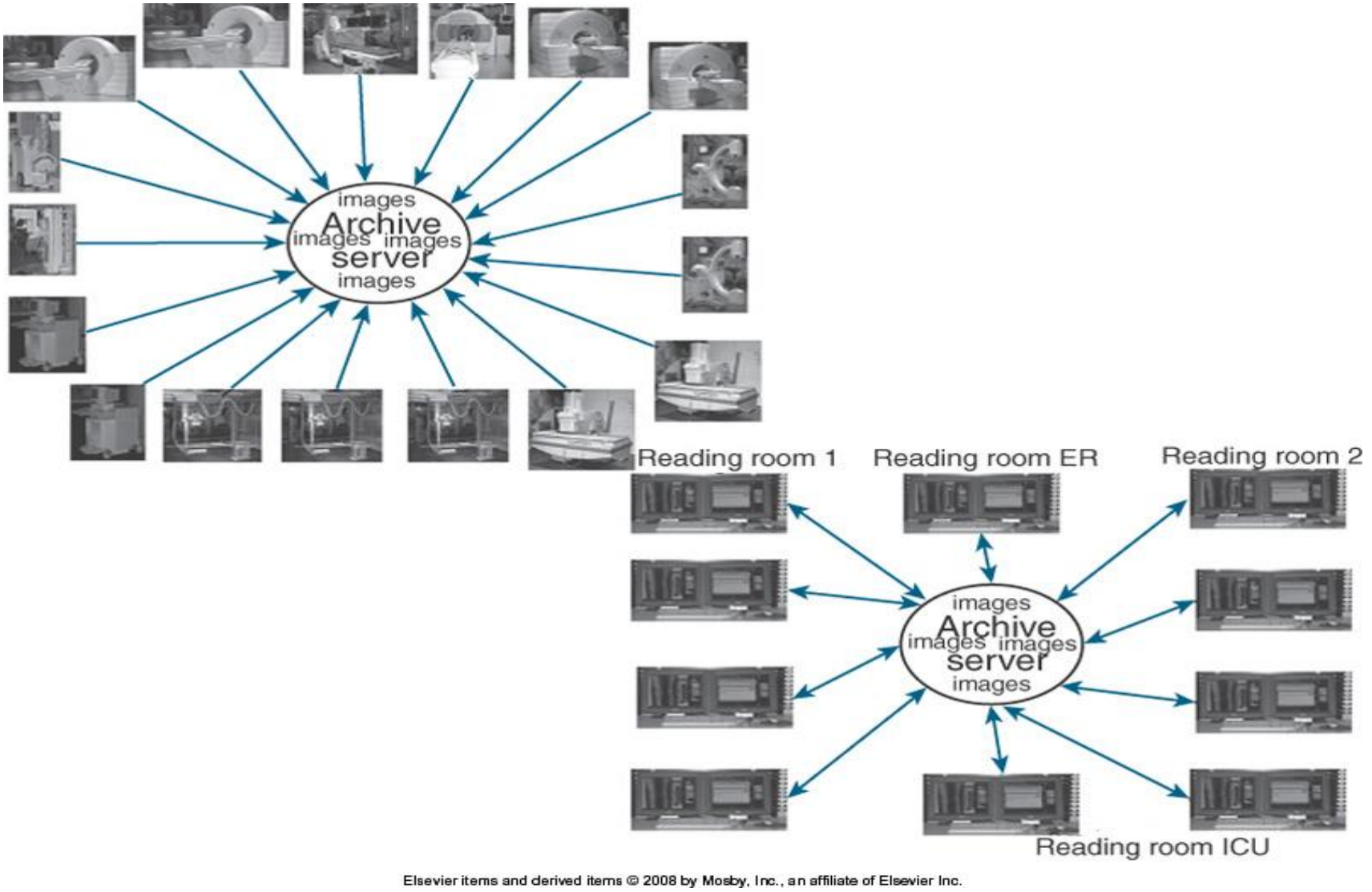
- Three common PACS architectures
  - Client/server-based
  - Distributed systems
  - Web-based systems

Client/Server-Based Systems

- Images are sent to archive server
- Display workstation functions as a client of the archive server
  - Accesses images based on a centralized worklist.
  - Person at the client chooses a name from the list.
  - Archive server sends the image data to the client.
  - The image data is only on the client while viewing.
  - Most systems allow basic image manipulation at the client.
  - Changes are saved on the archive server.



Client/Server-Based Systems



Client/Server-Based Systems

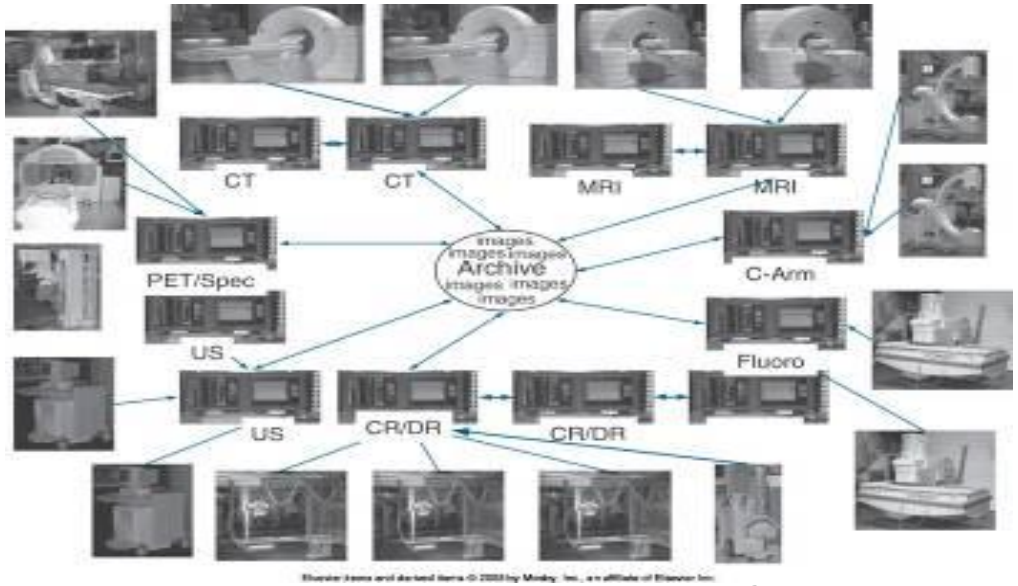
- Advantages:
  - Any exam sent to the PACS is available anywhere without other interventions.
  - Only one person can open the study with the intent to read it. Others that open the study receive a message that the study is open and being read.
  - There is no need to pull or send historic images to a particular workstation because the old studies are available with the new on the archive.

Client/Server-Based Systems

- Disadvantages:
  - The archive server is seen as a single point of failure.
    - If the archive goes down, the entire system is down and no image movement can take place.
    - Newly acquired images must remain at the modality until the archive is up and can receive the images.
  - System is network dependent.
    - Images are flying back and forth between the archive and the workstations.
    - Network can become bogged down.
  - Archive server is handling many requests at once and can become bottlenecked.

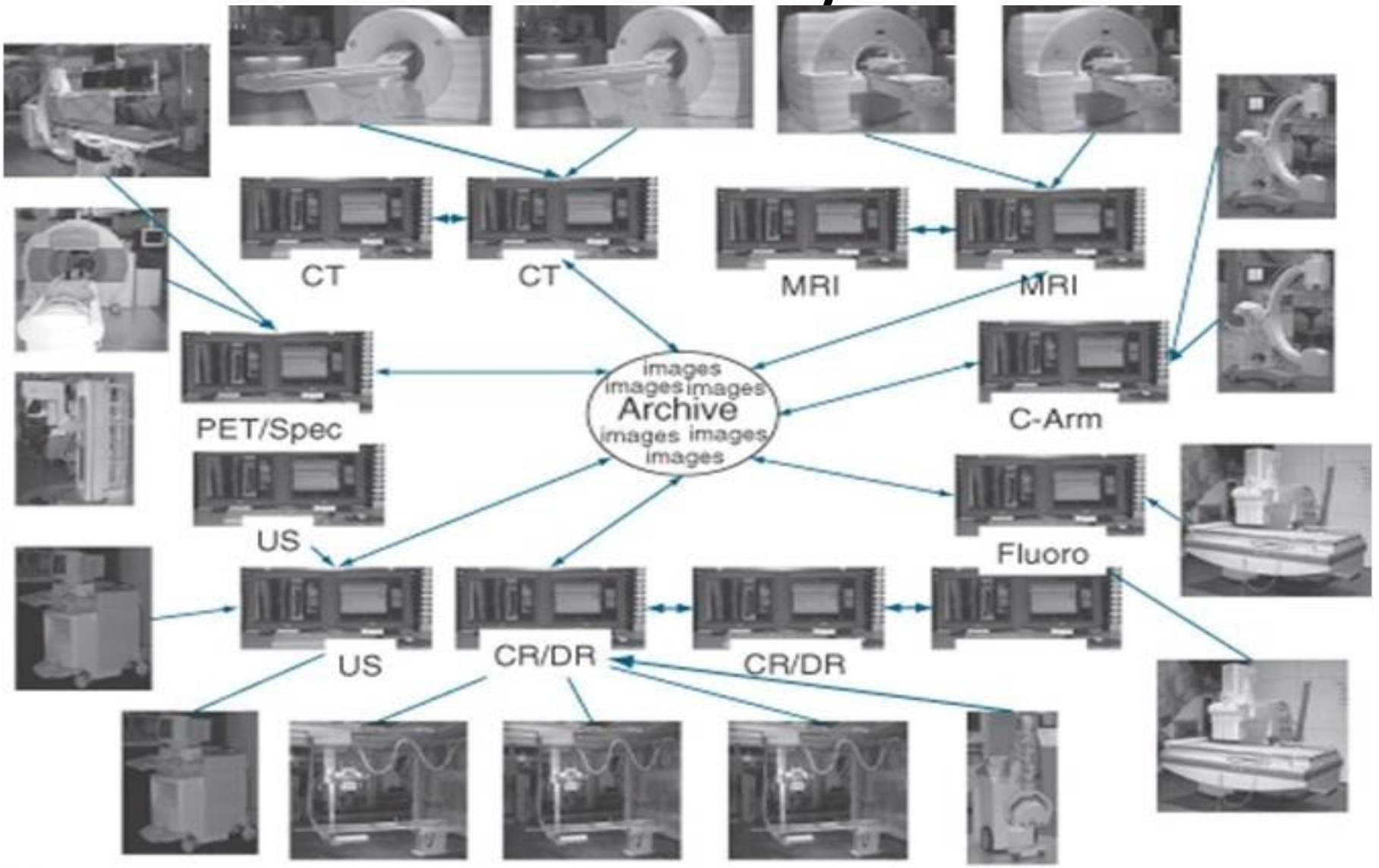
Distributed Systems

- Distributed systems are also known as *distributed* or *stand-alone models.*
- Acquisition modalities send the images to a designated reading station and possibly to **review stations**.



- In some systems the images are sent from the modality to the archive server, and the archive server distributes the images to the designated workstation.

Distributed Systems



Distributed Systems

- Reading station designations may be designed on radiologist's reading preferences.
- Example:
  - MRI may send to one station
  - CT sends to another
  - Or all cross-sectional neurologic images may be sent to one station, whereas all body imaging may be sent to another
- Designation is decided after extensive workflow observations.

Distributed Systems

- Workstations can query and retrieve images from the archive.
- All images are locally stored.
- Images are then sent to the archive server once the images have been read.
- Images remain on local hard drive of workstation until they are deleted by user or system rules.

Distributed Systems

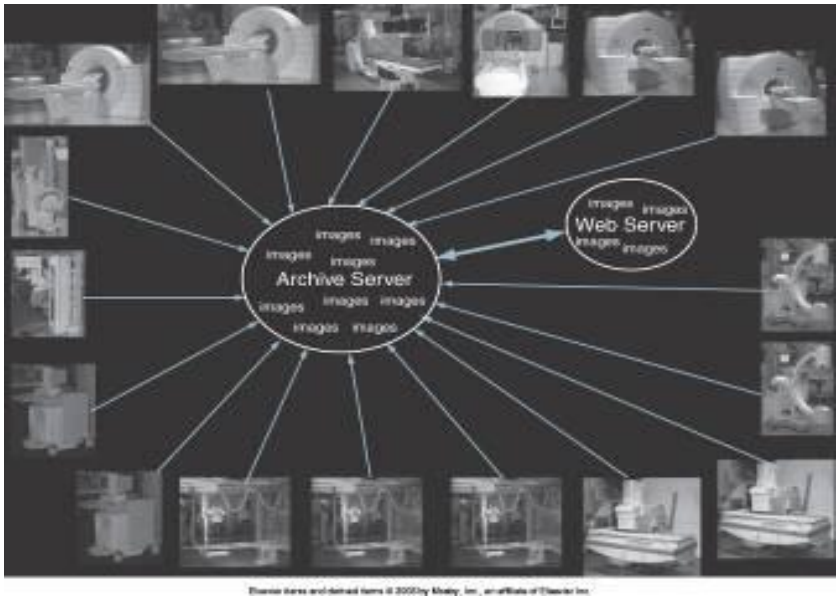
- Advantages:
  - If the archive server goes down, local reading at the workstations is not interrupted.
    - After archive comes back up, the images that have been changed and signed off are automatically forwarded to the archive to be saved.
  - PACS data is less likely to be lost because of multiple copies in various locations.
  - System is less dependent on network for speed.
    - User can work on one exam while workstation is pulling next exam to be read.
    - Workstation can fetch historic images based on rules set up by the user.
    - Fetching can be done while other exams are being read.

Distributed Systems

- Disadvantages:
  - Personnel rely heavily on system to perform image distribution correctly.
    - If distribution is wrong, then prefetching of historic exams will be wrong.
  - Each workstation has a different worklist; only one person at a time can work on that list.
  - It can be inconvenient to read additional studies.
    - Radiologist would have to move to another workstation to read the images.
  - Users must depend on query and retrieve function when nonscheduled exams arrive at workstation.
  - It is possible for two radiologists to be reading the same exam and not know it until they try to start dictation.
    - Paper requisition becomes an important piece of information.

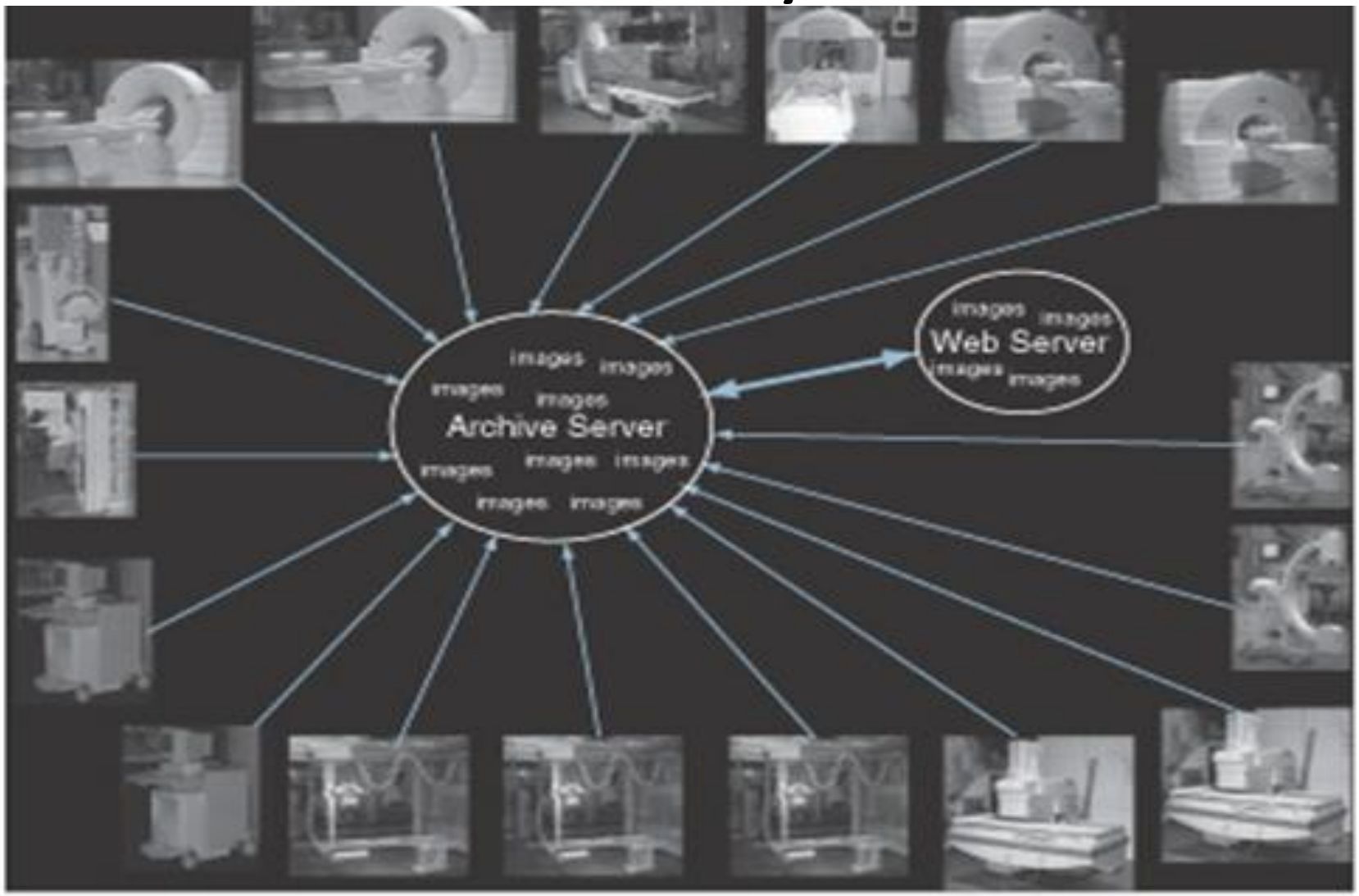
Web-Based Systems

- Web-based systems are similar to a client/server systems.
- Biggest differences are that images and application software are held centrally and loads to the client display.



- Only images are held at the archive.

Web-Based Systems



Web-Based Systems

- Advantages:
  - Hardware at the client can be anything that will support an appropriate web browser.
    - This condition allows for greater flexibility with hardware.
    - This can be a disadvantage because low-end PCs can be used and the image displays (monitors) may not be of diagnostic quality.
  - The same application can be used on-site and at home in teleradiology situations.
    - Teleradiology is the reading of images from outside the hospital walls.

Web-Based Systems

- Disadvantages:
  - System functionality may be limited because of software not being locally installed.
    - Bandwidth of the network connection limits the amount of data that can be transmitted.
    - Some programs are large and cannot be transmitted via a network.
  - Network is the biggest obstacle to performance.

Display Workstations

- Most interactive part of PACS
- Hands-on component
- Consists of the following:
  - Monitor
  - Computer with a mouse and keyboard
- Different hardware requirements for each system

Display Workstations

- Conventional film/screen radiography uses large multiviewer lightboxes.
- With early PACS, radiologists thought that they needed four to six monitors.
- Now, as radiologists have become more comfortable, the number of monitors has dropped to an average of two.
- Drop can be attributed to continued development of viewing software and better hardware.

Display Workstations

- Monitor
  - One of the most important elements
  - Several types of monitors
    - Cathode ray tube (CRT)

Figure 8-13 A cathode ray tube (CRT) monitor.
(Courtesy Agfa, Mortsel, Belgium.)

- Liquid crystal display (LCD)

Figure 8-16 A 2K monitor.
(Courtesy Barco.)

Display Workstations

- Monitor, continued
  - CRT
    - Heavy
    - Puts off a lot of heat
    - Very bright (good thing)
    - Can view from most any angle

Display Workstations

- Monitor, continued
  - LCD
    - Dropped in price and has risen in quality.
    - LCD will soon take over PACS display market because of its size, resolution, and lack of heat production.
    - LCD requires less maintenance.
    - LCD gives more light.
    - LCD can be used in areas with a high amount of ambient light.

Display Workstations

- Resolution and orientation of the monitor is a factor in determining which type of monitor is to be used.
  - Most cross-sectional imaging is read on a 1K square monitor.
  - Most computed radiography (CR) and digital radiography (DR) images are read on at least a 2K portrait monitor.

Display Workstations

- Number of pixels contained on a display is known as its resolution.
  - More pixels: The higher the resolution, the more information that can be displayed.
  - Resolution also is defined as the process or capability of distinguishing between individual parts of an image that are adjacent.

Display Workstations

- Pixels are arranged in a matrix.
- Common screen resolutions found on today's monitors are the following:
  - 1280 × 1024 (1K)
  - 1600 × 1200 (2K)
  - 2048 × 1536 (3K)
  - 2048 × 2560 (5K)

Display Workstations

- Medical displays are generally higher quality than displays for other applications.
- Radiologists use highest-resolution monitors available for the modality that is being read:
  - Mammography requires a 5K or 5-megapixel resolution.
  - Cross-sectional image only requires a 1K monitor.
  - If referring physician is not the primary doctor reading the exams, a 1K monitor would be sufficient.

Display Workstations

- Workstations can be categorized by use:
  - Primary reading stations for radiologists
  - Review stations for referring physicians
  - Technologist quality control (QC) station for technologist review of images
  - Image management station for the file room personnel
- Each has a specific, main purpose.
- Workstations are placed in strategic areas near the end-user of that particular need.
- Workstations may be made up of different hardware depending on demand and need of user and requirements of the software that will be used.

Radiologist Reading Stations

- Station is used by a radiologist to make a primary diagnosis.
- Station will have the highest-quality hardware, including best monitor.
- Computer hardware used depends on the needs of the PACS vendor but usually is robust, with little downtime.

Radiologist Reading Stations

- Keyboard and mouse can be customized to needs of department.
- Many different styles of mice are available.

- Access to the RIS is nearby.

Radiologist Reading Stations

- Dictation system is near or is connected to PACS station.
- Many systems are integrating the RIS and dictation system within the PACS software.
- Grouping allows a more seamless workflow with little to no paper.
- Station streamlines the completion of the study.

Physician Review Stations

- Station is a step-down model of the radiologist's reading station.
- Station may have the same level of software but may reduce some advanced functions.
- One of the most important features is ability to view current and previous reports with images.
- Many vendors are integrating the RIS functions with PACS software.

Physician Review Stations

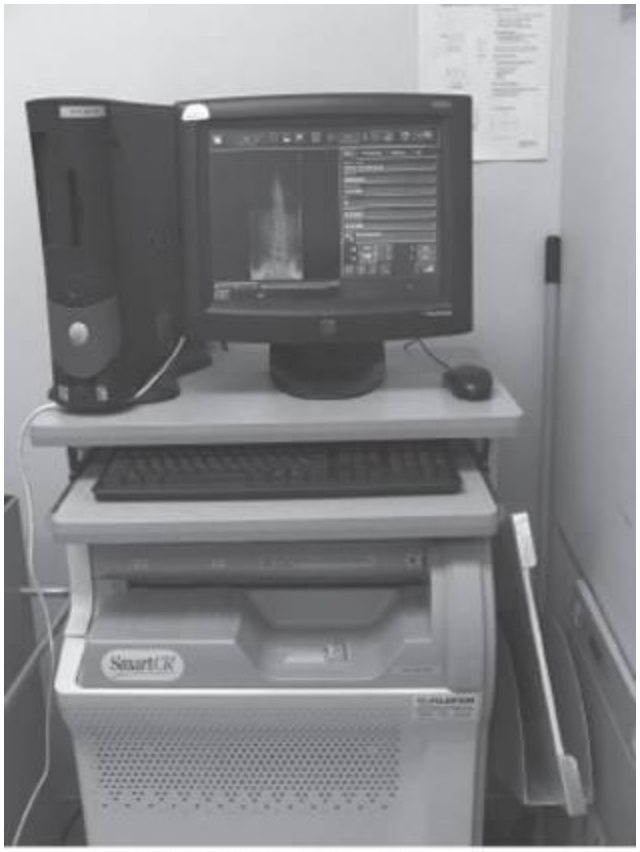
- Most referring physicians want to read radiologist's report along with viewing images.
- Many times, report is more important to them than the images.
- Software may be loaded on a stand-alone station that is dedicated to viewing images.
- Or, software may be delivered over a web browser on any personal computer within an office or floor.

Physician Review Stations

- In high-volume areas such as the emergency room and intensive care unit, there are dedicated PACS workstations strictly for image viewing.
  - These may have the higher-end monitors, but many may have a lower-end monitor because of the costs.
- One of the greatest advantages of a PACS is the ability to view the same set of images in multiple locations at one time.
  - Referring physician can pull up the patient's images in the office and read the radiologist's report and then call the radiologist on the phone and consult while both parties are viewing the same set of images.
  - Continuity and speed of patient care has shown improvement with the use of PACS.

Technologist QC Stations

- Used to review images after acquisition but before sending them to the radiologist
  - May be used to improve or adjust image-quality characteristics
  - May be used to verify patient demographic information
  - Placed between the CR and DR acquisition modalities as a pass-through to ensure that the images have met the departmental quality standard



Technologist QC Station

- Generally has a 1K monitor.
- Does not have the resolution capabilities of the radiologist's reading station.
- Care required of technologist when manipulating images not to change the appearance too much from original acquired image.
- Technologist should consult frequently with the radiologist to ensure quality.
- Station can also be used to query and retrieve historic images to check previous pathologic conditions or body characteristics.
- Station can help with the selection of technical factors or procedural protocol.
- QC station can afford same benefit as pulling the film jacket.

The File Room Workstation

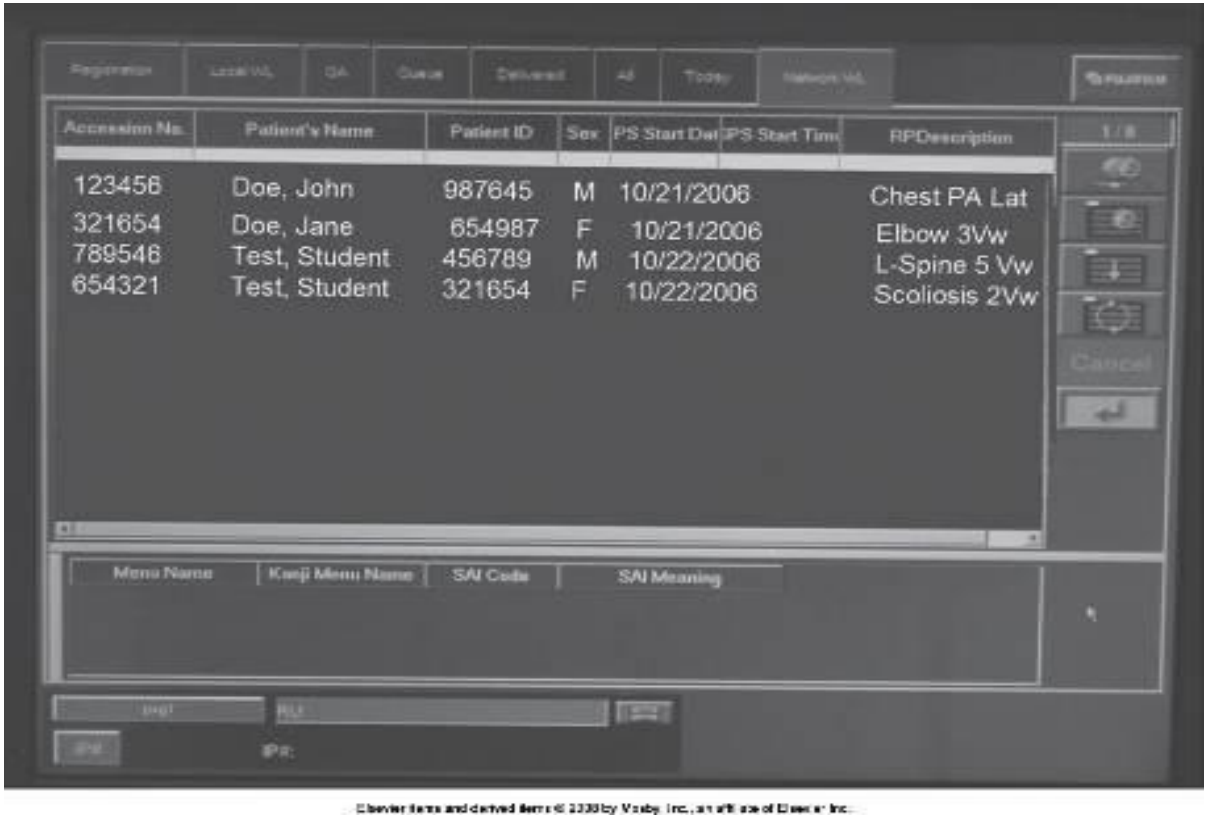
- Before PACS, file room was a large open room with endless rows of shelves full of film jackets.
- Today, it may be as simple as several computers and a dry laser to make copies for outside needs.
- Workstation may be used to look up exams for a physician or to print copies of images for the patient to take to an outside physician.
  - Many hospitals are moving away from printing films because of the cost.
  - Hospitals are moving toward burning compact disks (CDs) with the patient's images.
  - CDs can be made quickly and at a reduced cost compared with film.

Common Functions

- Navigation functions
- Image manipulation and enhancement functions
- Image management functions
- Advanced workstation functions

Navigation Functions

- Used to move through images, series, studies, and patients



- Worklist used to navigate through patient files
  - Customizable for the user

Navigation Functions

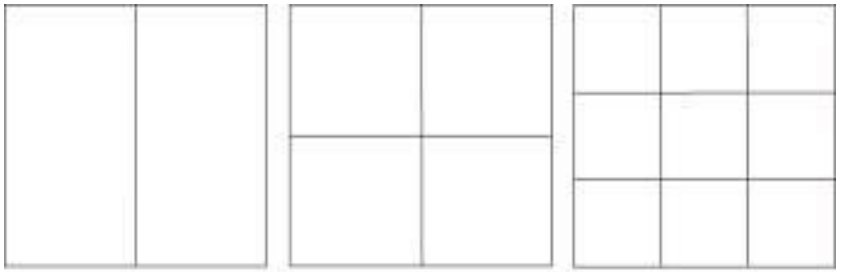
- Modern PACS software conforms to the windows look and feel:
  - Use of grab bars on the right hand side of windows to scroll through a list
  - Activation of the scroll wheel on the mouse to scroll through the list

Navigation Functions

- Mouse is a useful navigation tool.
- Right mouse button offers many shortcut features in a menu of frequently used tasks and applications.
- Hanging protocols are available:
  - Each user has the ability to set up a custom hanging protocol.
  - Protocol is defined as how a set of images will be displayed on the monitor.

Navigation Functions

- Hanging protocols



  - Example:
    - CT exam is selected.
      - Can be viewed four images on each monitor.
    - CR image is selected.
      - Can be viewed as one image on each monitor.
  - Protocol can also be specified to show the previous exam on one monitor and the current exam on the other.
  - Once set, the most efficient study navigation is determined.

Study Navigation

- A study in PACS is the current or previous exam being viewed.
  - Study may consist of two or three single images such as the case with CR and DR.
  - Study may contain several series of images such as the case with MRI.
  - Images can be simply paged through with the scroll wheel or arrows on the keyboard.

Study Navigation

- Images can be run through in stacks.
  - Stack mode of scrolling through images made is called “cine.”
    - Cine means to move through frame by frame of the series of images.
  - Study may have an automatic setting that will run through the images at a preset pace.
  - Cine function is used most often in cross-sectional imaging.

Study Navigation

- Icon may be available for the following:
  - To move between a patient's various studies
  - To open the next unread patient file in the worklist
  - To close patient or study icon
    - Closes the active patient or study
    - Pulls up the worklist or moves to the next unread patient
- Customizable rules can be set up per user to optimize workflow.

Image Manipulation and Enhancement Functions

- Tools
  - Window/level

- May be a default function of the left mouse button.
  - By depressing and holding down the mouse button and moving the mouse up and down and left and right, the window and level can be adjusted.
- Window represents the range of gray values.
- Level represents the center value of the range.
- A change in the window and level appears to change the brightness and contrast of the image.

Image Manipulation and Enhancement Functions

- Tools, continued
  - Annotations

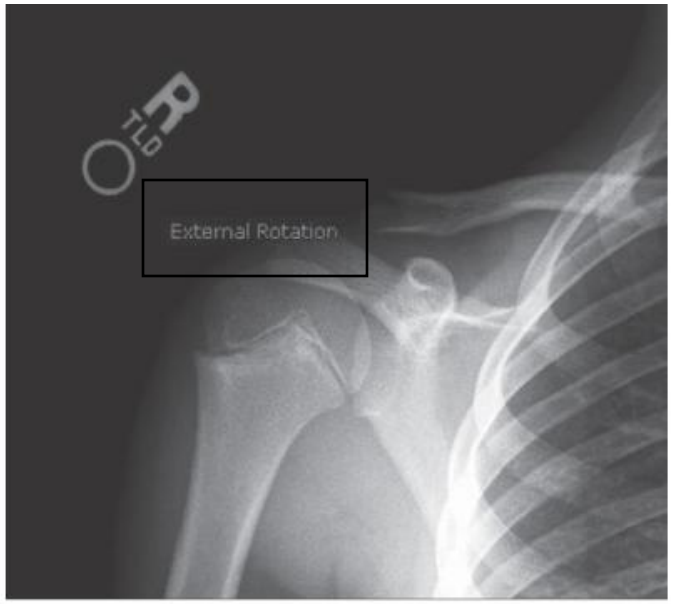


Figure 8-26 Text annotations can be placed directly on the image.

- Annotations are NOT to be used to label left or right to indicate the patient's side.
- Annotations are used to indicate prone or supine, 30 minutes, upright or flat.
- Any other image information is appropriate.
- Radiologist will place arrows or circles around pathologic or questionable areas.

Image Manipulation and Enhancement Functions

- Tools, continued
  - Flip and rotate

- Tool is used to orient the image in the correct anatomic hanging position.
- Tool is usually a left-to-right flip and a 90-degree clockwise and counterclockwise icon.
- Use of lead markers is important to ensure that the radiologist is reading the correct side.
- Digital R and L may not be upheld in court during a legal case because of the ability to mark anywhere on the image and flip and rotate the image into any layout on the screen.

Image Manipulation and Enhancement Functions

- Tools, continued
  - Pan, zoom, and magnify
    - Tools are used primarily by the radiologist to increase the size of an area on the image.
    - Magnify usually magnifies a square area of the image.
      - Square can be moved around the image to quickly see various areas magnified.
    - Pan and zoom functions are usually used together.
      - Image is first zoomed up to the desired magnification level.
      - Pan icon is activated.
      - Zoomed image can be moved around to view the different areas of the image.

Image Manipulation and Enhancement Functions

- Tools, continued
  - Measurements
    - Various measurement functions are found on a PACS station.
    - Most common is the distance measurement.
    - Size of a pixel is a known measurement, so the software has the ability to measure structures on the image based on this.
  - Another common measurement is an angle measurement.
    - Can give an angle measurement between two structures
    - Commonly used when reading spine studies

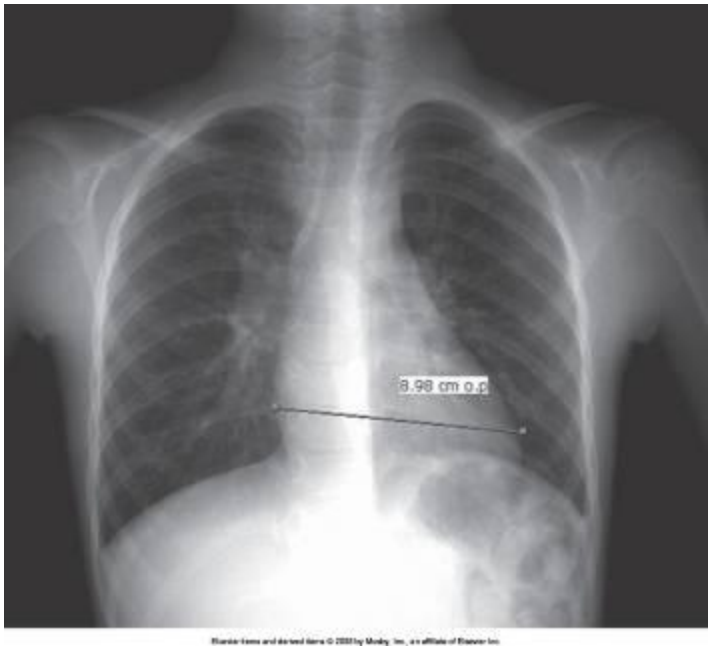
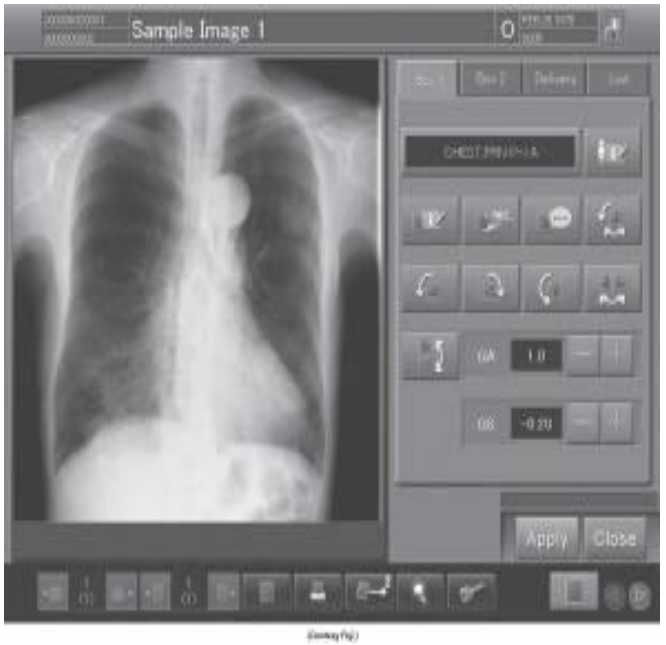


Image Manipulation and Enhancement Functions

- Tools, continued
  - Measurements
    - Region of interest
      - Measurement tool determines the pixel intensity of a certain area.
      - Each type of tissue or fluid has a different intensity of reading.
      - Radiologist can make a determination whether something is solid or fluid.

Image Management Functions

- Patient demographics



  - Patient demographics must be correct.
    - If demographics are not correct at the archive level, the images could be lost.
  - Changes should only be made when the information is absolutely known to be wrong.
  - Many hospitals allow only certain persons the access to change demographics just to keep the errors to a minimum.

Image Management Functions

- Query/retrieve icon
  - Used to retrieve on demand any studies from the archive
  - Allows user to query a study on multiple fields
    - Patient's name or identification
    - Date of service
    - Modality
    - Diagnosis code or comment field

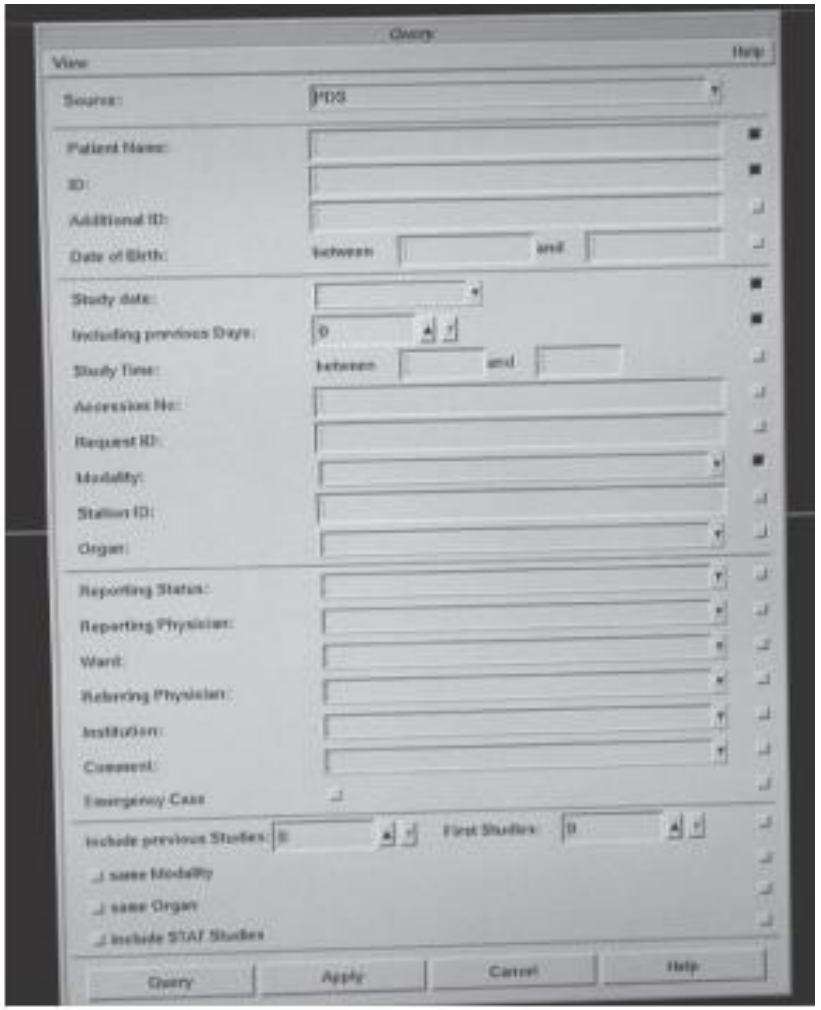


Figure 8-31 The user can query images from the archive using various search parameters.

Image Management Functions

- CD burning option
  - Feature may only be available in the file room to control the CDs that are sent out.
  - HIPAA (Health Insurance Portability and Accountability Act) compliance must also be maintained.
- Copy and paste
  - Function is used with the web-based systems when creating presentations for conferences.
  - Patient information must be removed from the image before it is placed into a presentation.

Image Management Functions

- Print films
  - Printing is usually only done in the file room so that control can be maintained over the printed films for HIPAA purposes and cost reasons.
  - Workstations may be connected to paper printers for quick consults and for medical records.

Advanced Workstation Functions

- Advanced functions are usually placed on specialty workstations for the radiologist, and some are found on the technologist QC station to further enhance the images. The following is a bulleted list of some of the most common advanced functions:
  - Multiplanar reconstruction (MPR)
  - Maximum intensity projection and minimum intensity projection (MIP and MinIP)
  - Volume rendering technique
  - Shaded surface display
  - Stitching

Reading Station Advanced Functions

- Multiplanar reconstruction (MPR)
  - MPR is one of the most commonly used three-dimensional rendering techniques.
  - When doing a CT scan of a patient, thin axial slices can be acquired of a volume of tissue.
  - Slices can then be loaded into the MPR software, and a reconstruction in another plane can be produced.
  - Most common application is producing coronal images from the axial set to reduce radiation to the patient and scan time at the modality.

Figure 8-32 An MPR image.

Reading Station Advanced Functions

- Maximum intensity projection and minimum intensity projection (MIP and MinIP)
  - Function is used to visualize vessels (MIP) and air-filled structures (MinIP).
  - Function is commonly performed after injection of contrast medium on CT and MRI studies.
  - Contrast medium shows areas of strictures and blockages within the vessels.

Figure 8-33 An MIP image.

Reading Station Advanced Functions

- Volume rendering technique
  - Function is similar to MIP.
  - Function allows user to assign colors based on the intensity of the tissue.
  - Bone, contrast medium, and organs can be visualized using various colors.
  - Function uses a histogram-type graph to differentiate the various structures.

Figure 8-34 A VRT image.

Reading Station Advanced Functions

- Shaded surface display
  - Using a threshold of pixel intensity values, everything below the threshold is removed and everything above is assigned a color and is shown as a three-dimensional object.

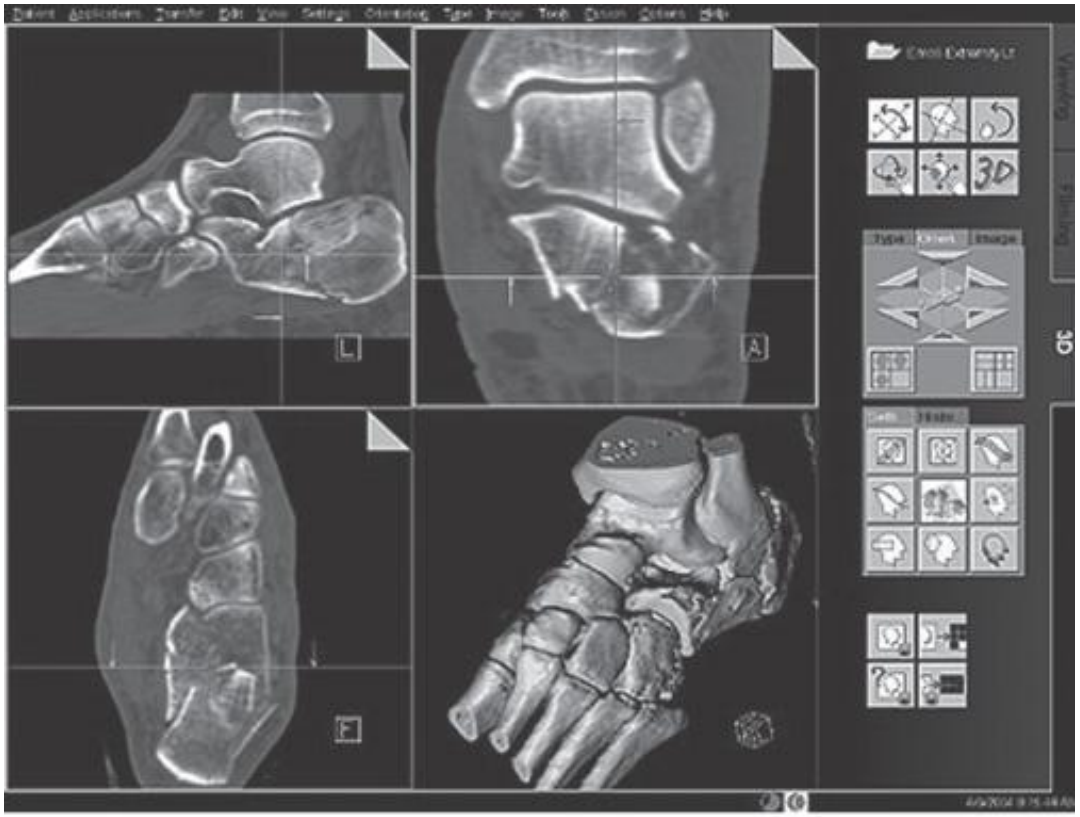


Figure 8-35 A 3D shaded surface image.

Technologist QC Station Advanced Functions

- Stitching
  - Stitching is used when multiple images need to be put together in one image.
    - Most common application is for full-spine radiographs or a scoliosis series.
      - » Exam was traditionally performed on a 3-foot film and was processed.
    - CR manufacturers have developed a 3-foot CR cassette that contains multiple image plates (IPs).
      - » Each of the IPs is scanned through the reader, and the individual images are sent to the QC workstation.
      - » Software interpolates images and connects them using known markers from the IPs.
      - » Technologist has the ability to adjust the connection of the images.
    - Long leg images are used for leg-length discrepancy.
    - If the special 3-foot cassettes are not available, a radiopaque ruler can be used to ensure that the images are stitched at the right area.

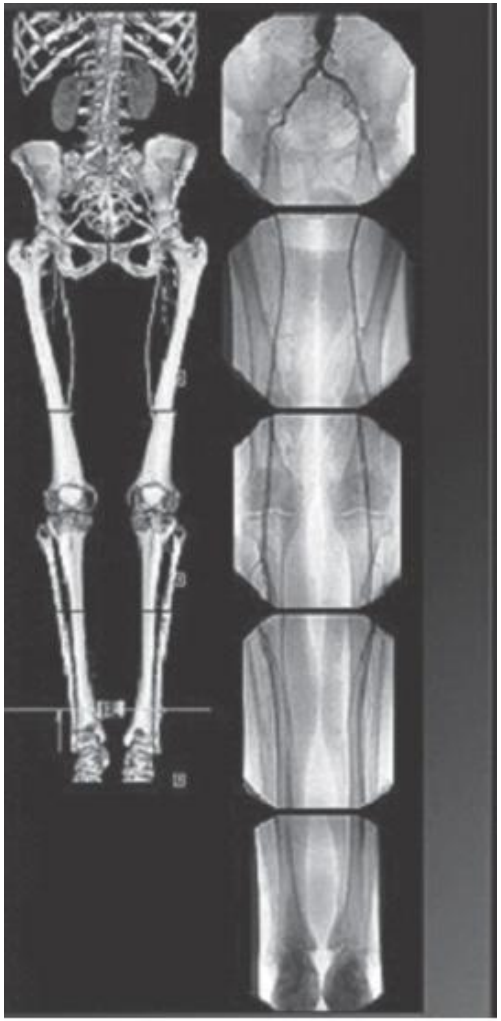


Figure 8-36 This image was stitched together from two separate images.

Image Postprocessing

- Many other advanced workstation functions are available to be added to the PACS workstation. This is a growing field with advancements coming each year. Specific information about how to perform these procedures can be found in the vendor's user manual.

PACS integration to CDIS

- CDIS(Clinical Devices Information System)
- Medical image/data other than PACS
  - ECG, Patient monitor, Ventilator, defibrillator, Ophthalmology, Function test, Clinical pathology
- HL7, XML, RS232C and DICOM are the communication formats in use.

Summary

- A PACS consists of digital acquisition, display workstations, and storage devices interconnected through an intricate network.
- Digital imaging and communications in medicine (DICOM) is a universally accepted standard for exchanging medical images between the modality, viewing stations, and the archive.
- A display workstation is any computer that a health care worker uses to view a digital image, and it is the most interactive part of a PACS.
- The archive is the central part of the PACS and houses all of the historic data along with the current data being generated.
- Workflow is how a process is done step by step or how a task is completed.

Summary

- System architecture is the basic organization of a system, come to life in its components, their associations to each other and the environment, and the principles leading its design and development, or in other words, system architecture can be defined as the hardware and software infrastructure of the systems workflow.
- Common system architectures found with a PACS are client/server-based systems, distributed or stand-alone systems, and web-based systems.

Summary

- Display stations can be categorized by their means of use, such as primary reading stations for radiologists, review stations for referring physicians, technologist QC stations for technologist review of images, and image management stations for the file room personnel.
- Many functions are available on a PACS workstation, and each set of functions can be broken down into four categories: navigation functions, image manipulation and enhancement functions, image management functions, and advanced workstation functions.

Thanking you for your attention