APPH 226:

PACS

Objectives: 8.1 – 8.5

MRT Program

PACS Introduction

- PACS refers to a broad range of technology used for digital radiography
- With a computer network, PACS allows the integration of image acquisition devices, workstations, and storage systems
- PACS has made a huge impact on physicians, technologists, radiologists
  - Improves image interpretation, processing, viewing, storage and recall
  - Workflow, accessibility of images (including remote access), turnaround times, and patient care

PACS

- Massive amounts of data pass through any PACS and there is almost always demand for access to data from technologists, radiologists, and physicians
- In addition to the hardware and software, a necessary component of PACS is a skilled IT team to keep it running smoothly
  - Techs also need to have a basic understanding of PACS
    - Networking, digital image formatting, image acquisition, workstations, data storage and image distribution

Networking

- A group of two or more computers linked together is a network
- Network and PACS are two distinct entities, but they play a major role with each other
  - If the network is poorly designed, it will affect the PACS system
    - Technologists will not be able to send images
    - Radiologists are unable to view/read images
    - Referring physicians will be unable to access images or reports

Network Classifications

- Many different types and configurations of computer networks
- In radiography, these two categories are applicable
  - LAN
    - Local area network
    - Linked computers that are close together (i.e. in the same building)
  - WAN
    - Wide area network
    - Computers that are further apart and must be connected by telephone lines, cables or radio waves



LAN

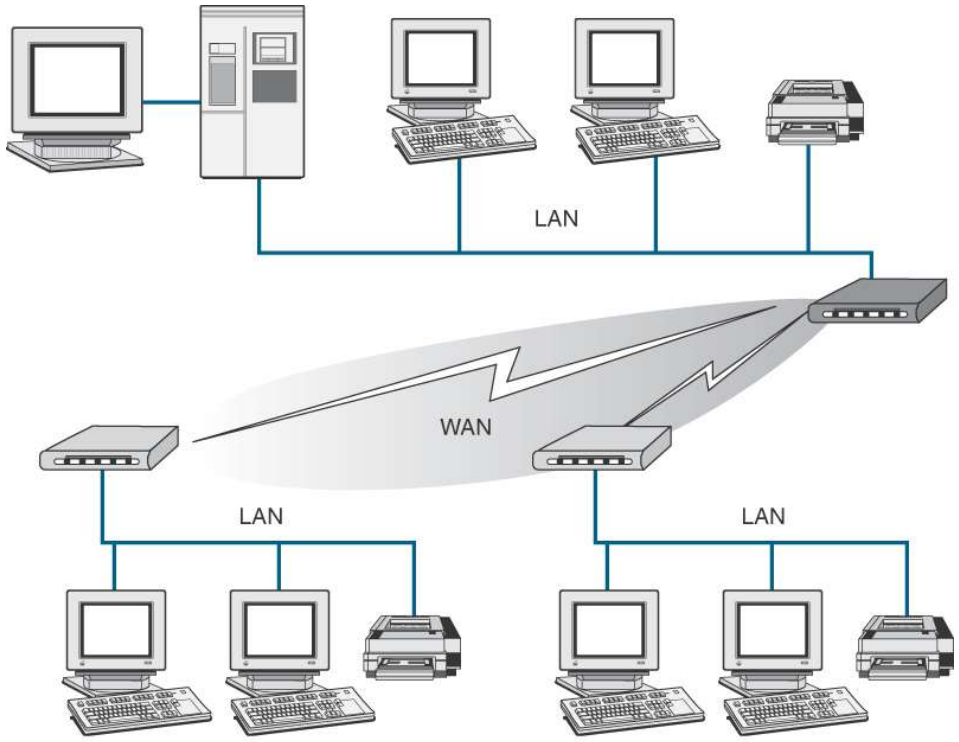
- Computers that can share information and devices on the same network
  - Networked with cables or wireless access points
- Less expensive to install, and faster than WANs due to their smaller size
- Has the fastest communication technology as it does not require as much equipment and resources to complete the network
- Can have several LANs connected to create the WAN



WAN

- Network spans a large area: city, province, country, continent or world
- Used to connect computers that are not physically connected with cables, but connected through phone lines, satellite links, or other types of communication cables
- The operating costs are high due to the usage of long distance communication links
  - Often communication links are outsourced to a separate company
  - Covering large distances with high speed equipment is expensive

LAN and WAN



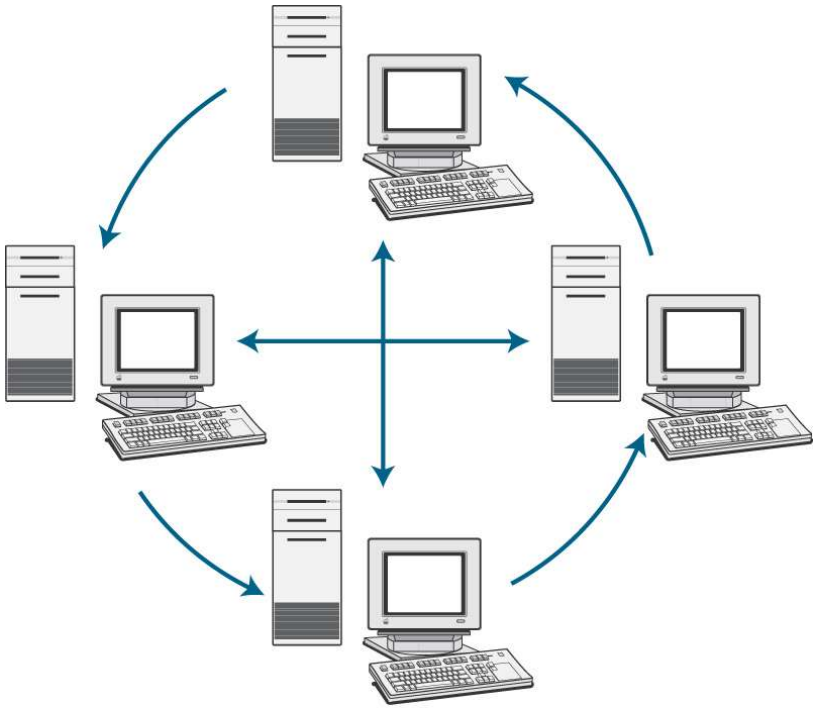
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Network Connections

- Wired
  - Networks that are linked by a physical connection
  - Telephone lines, copper or fiber optic cables
- Wireless
  - Networks that use radio waves to transmit data between computers

Networks

- Peer – to – peer
  - Aka P2P
  - Popular set up for home network or small businesses
  - Each party has the same capability and any party can initiate communication
  - Every computer is considered equal
    - In control of its own information and operation



Resources are shared among equals in a peer-to-peer network.

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Networks

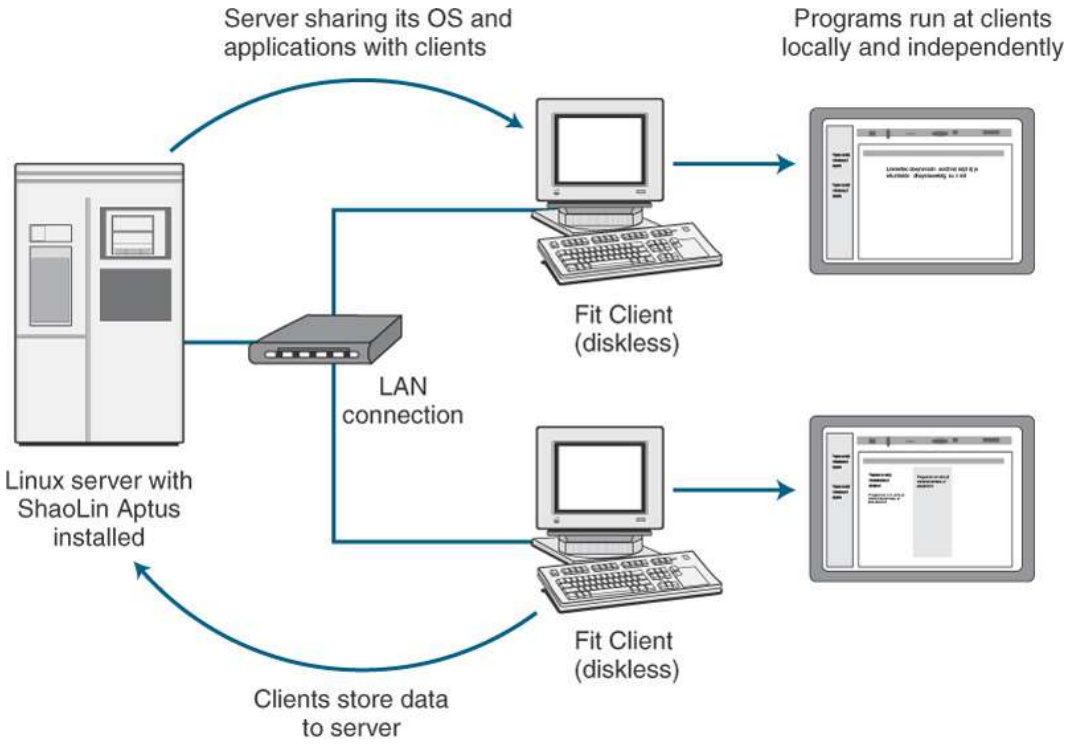
- Client-Server Based Network
  - Computers are classified as either clients or servers
  - Centralized computer (server) controls operations, files and sometimes computer programs (clients) that are attached to the network
  - Server
    - Computer that facilitates communication between and delivers information to other computers
    - Centralized location for storage and retrieval of information
    - Passive, waits for requests from other computers (clients)
      - Allows users to move from computer to computer and access files from a central location
    - Can accept connection from a large number of clients



Networks

- Client-Server Network
  - Client
    - Can connect to a small number of servers at one time
    - Can be referred to as a node
    - Used to request information
      - The server can send entire file for processing. When completed the client sends the entire changed file back to the server for storage
      - Another option (client network) - instead of the entire file being sent for processing, the server processes the resource as requested by the client, and only the results are returned to the client, not the entire file

Server Based



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Network Components

- Computers
- Typical for three types of computers to be found on a network
  - Server
  - Thin Client
  - Thick Client

Network Components

- Server
  - Manages resources for other computers, servers and networked devices
  - Can also serve as data storage, house applications or perform other tasks
  - Usually is dedicated to one task for the network
    - Ie. Print server, archive server, etc.
  - Is the most robust computer on the network
- Thick Client
  - Computer that can work independently of the network
  - Can process and manage its own files
  - Networked so that it can share resources
  - Typically is a high end computer that does high level processing for specific purpose
    - i.e. CT postprocessing, 3D reconstruction
- Thin Client
  - Any device found on a network that requires a server to complete its tasks
  - Requests services and resources from server
  - Almost anything attached to the network can be a thin client
    - i.e. computer, printer

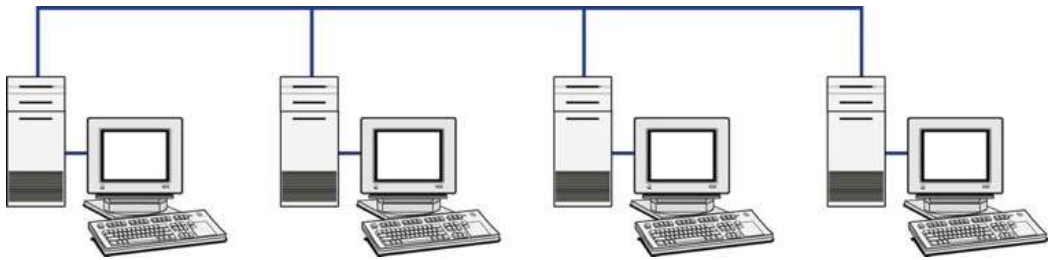


Topology

- Geometric arrangement of a computer system
- Common topologies are:
  - Star
  - Bus
  - Ring
  - Mesh
- LAN can be a combination of these, typically using Ethernet cables to attach computers to the network

Bus Topology

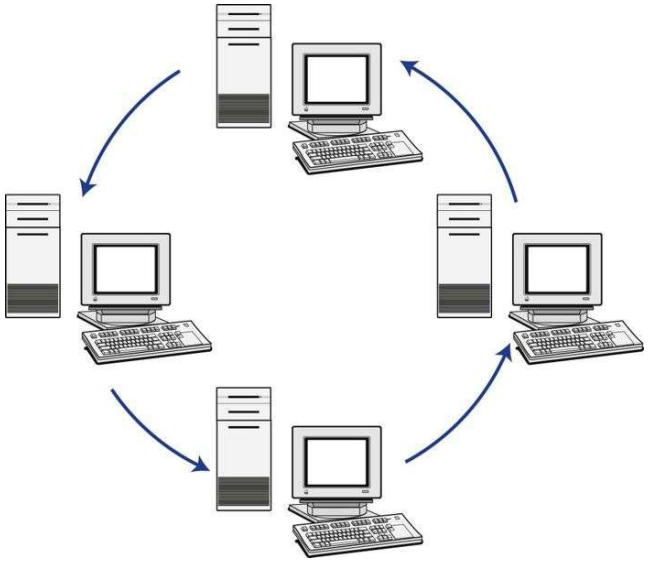
- All devices are physically attached to and listen for communication on a single wire
- Single point of failure: the wire
- If there is a break anywhere on the wire, the entire network will go down
- All information is broadcast and received by the computers connected to the single wire





Ring Topology

- Devices are connected in a circle
- Data travels in one direction until it reaches the correct receiver
  - If there is a break anywhere, the network comes to a halt

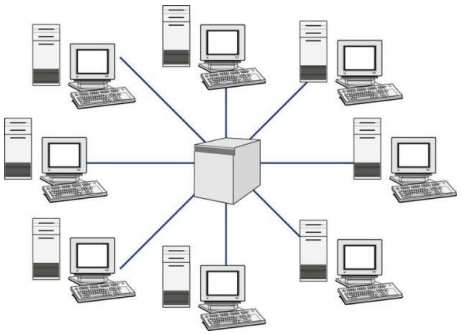




https://emilylayla.files.wordpress.com/2011/10/notepassing1.jpg

Star Topology

- Devices connected to a central hub or switch
- Data sent through the hub to the destination device
- Data transmitted can be through another hub or switch to an adjacent network or directly to the device
- Most commonly used network topology

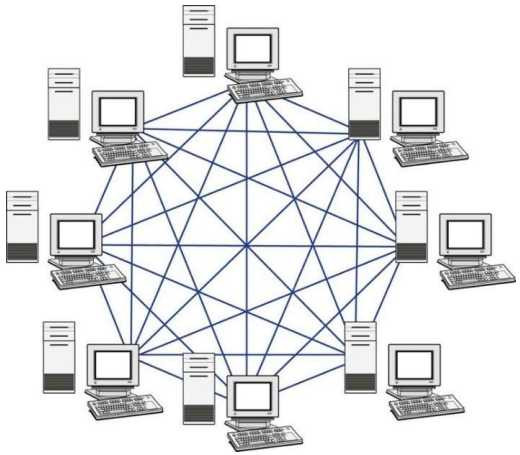




Mesh Topology

- Multiple pathways to connect devices and networks
- Redundancy built in
  - More than one pathway between devices
- Most often used to connect networks to other networks





DICOM

- Stands for : Digital Imaging and COmmunications in Medicine
- Almost a universally accepted standard for the exchange of **medical images** between networked devices
  - Standards are continually updated
- Before DICOM, there were many issues trying to send images over a network
  - Incompatibility between vendors

DICOM

- Scope extends beyond radiology, other specialties utilize it also (i.e. pathology, cardiology)
- DICOM standard is used by all vendors, but some vendors may also have additional information – often proprietary
- Consists of 20 different parts, from image display parameters to media storage
- Not every device will conform to every part of DICOM, but just the parts required to perform the tasks

DICOM

- Ensures all devices and equipment are speaking the same language
- UID – Unique Identifiers
  - DICOM assigns numbers to images so that image sets cannot be confused with images from another system
    - Typically based on vendor number, serial number, date, time, patient number, study/image number
    - E.g. 1.4.523.745645.2.201811071320.876234.1

Health Level Seven (HL-7)

- Universal standards used for most clinical and administrative data
  - i.e. demographics, reports, claims and orders
- Like DICOM, HL-7 has many components, and used at many levels within the hospital system
- Generally used in communication between HIS (hospital information system) and RIS (radiology information system)

HIS, RIS and EMR

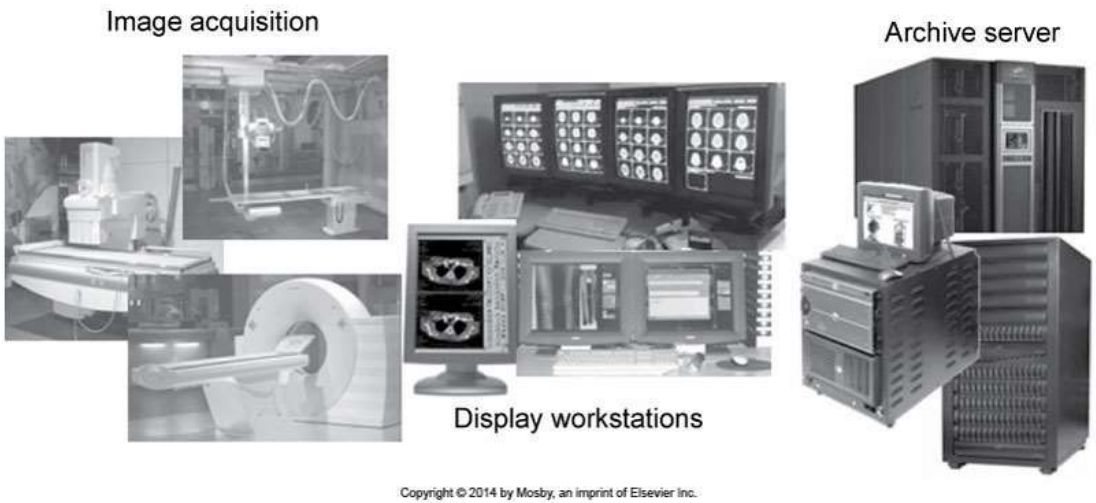
- HIS – Hospital Information System
  - Holds patient's full medical information
  - E.g. billing information, inpatient orders
  - Considered the core information system for patient management within the hospital
    - Streamlines process flow within the hospital
- RIS – Radiology Information System
  - Holds all radiology specific patient data
  - E.g. scheduled exams, radiologist's report
  - Considered the core information system for electronic management of all things related to imaging
    - Smoother workflow and improves quality of reporting
- Together HIS and RIS improve efficiencies by reducing redundancies in test ordering

HIS, RIS and EMR

- EMR – Electronic Medical Record
  - Can be part of HIS or run alongside it
    - HIS maintains EMR by recording vitals, test results
  - Contains all of the patient's records
    - Includes lab results, radiology reports, pathology reports, notes
    - Interfaces with systems to retrieve reports to be viewed in one place
    - Also interfacing with PACS to view images
      - The user only has to log into the EMR to access all the information, vs logging into RIS, HIS, and PACS separately

PACS Fundamentals

- PACS is basically an electronic version of the radiologist reading room and the file room
- Break it down into fundamental components:
  - Image acquisition
  - Display workstations
  - Archiving



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Image Acquisition

- Images are acquired in a digital format
  - This can be any modality – e.g. U/S, Nuclear Medicine, CR/DR, CT, MRI etc…
- Can be transferred by a computer network
- Allows for soft copy reporting
  - No need for films in hardcopy for radiologist to read
  - Radiologists were not viewing the images at the modality (slowing down scanning process)
- Images must comply with DICOM standards

Types of Workstations

- Hardware and software is dependent on purpose
  - Review Workstation
    - For referring physicians
  - Radiologist Workstation
  - Technologist Workstation
    - QC for technologists
  - Image Management Workstation
    - File room personnel


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Display Workstations

- Any computer that can be used to view a digital image
- Most **interactive** part of PACS
- Can be used inside and outside of the dept
- Receives images from the archive or modalities for viewing
- Has software to allow minor image manipulation to optimize viewing of the image
  - Some workstations will have more advanced software to allow for more complex image manipulation

Review Workstations

- Each one has a monitor, computer, mouse and keyboard
  - Software to fit requirements
- Monitors are one of the most important elements
  - Most common configuration is 2 or 4 screens
  - LCD more popular than CRT due to size, resolution and lack of heat production
  - Typically 1-2K monitors used
  - This is for display or viewing, not the medical display monitor
    - Not for the primary diagnosis
    - Can be used by referring drs, techs, etc…

Review Workstation (Physician)

- Step down from Radiologist Workstation
- Typically has the same level of software, but with some of the functions removed
- Important feature is the ability to view current and previous reports alongside the images
  - Important for referring physicians
  - Major improvement on patient care with digital – physicians can consult, access images and radiologist reports from anywhere with PACS access vs physically meeting radiologist to consult


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Radiologist Workstation

- Used by a radiologist when making a primary diagnosis
- Has the highest quality hardware, and the best monitor – 5K minimum
- Computer hardware is usually very robust, requiring little downtime
- Generally there is access to a nearby RIS with a dictation system, or it could be connected to the PACS station

Radiologist Workstations



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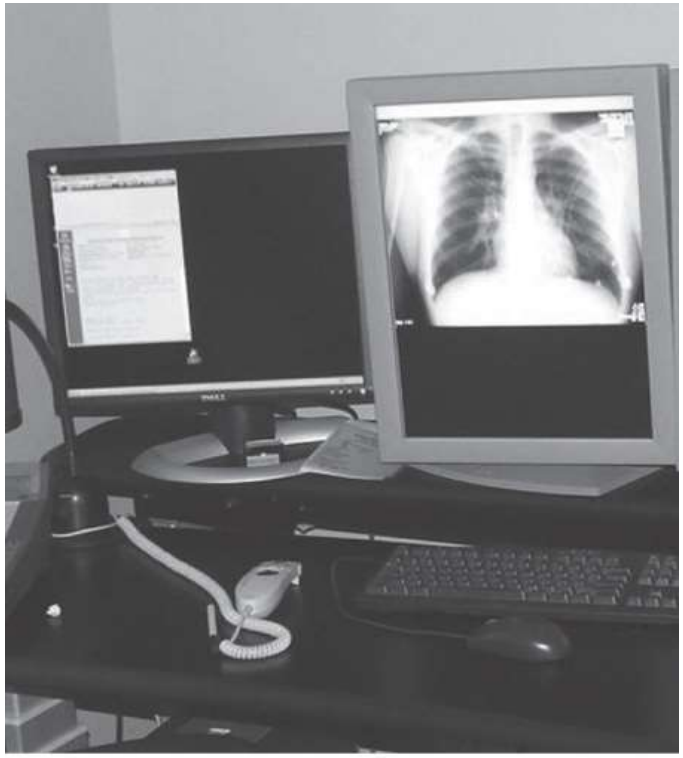
Technologist Workstation

- For reviewing images after acquisition but before sending to the radiologist
- QC station used to:
  - Adjust image characteristics
  - Verify demographic information
  - Often this is in the department as a pass-through to ensure images have met standard
  - Review previous images
- Generally has 1K monitor
  - Techs are **not** to save any changes to the original acquired image
    - This can affect the ability for the radiologist to manipulate the image

Tech PACS Station



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Image Management Workstation

- Used to look up examinations or print copies of image
  - Many sites opting to burn CDs vs print laser films as CDs are more cost effective
    - Includes a "mini" DICOM viewer software
- File room personnel may be responsible for making corrections to patient demographics
- If incorrect demographic information is attached to an image and sent to archive, it can be difficult to locate the images later
- Archive is a database and is only as good as the information put into it



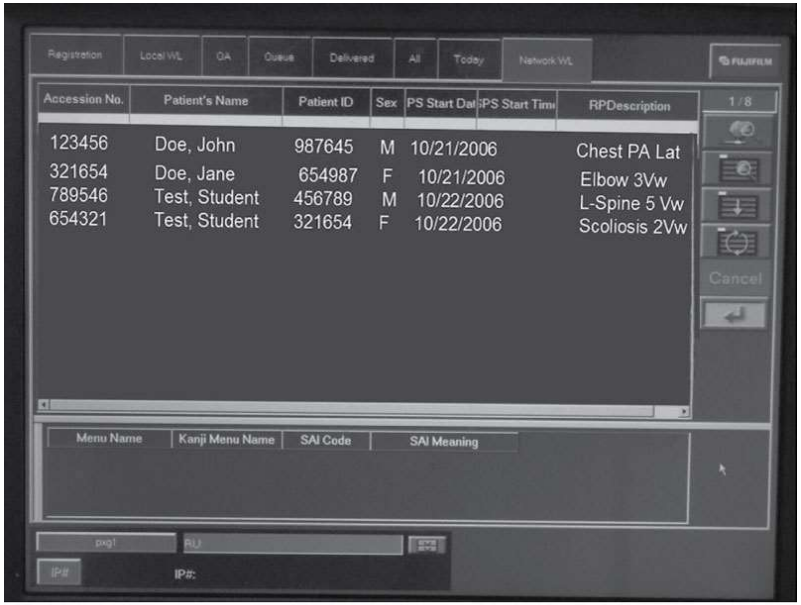
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Common Functions of Workstations

- Navigation
- Image Manipulation/Enhancement
- Image Management
- Advanced

Navigation Functions

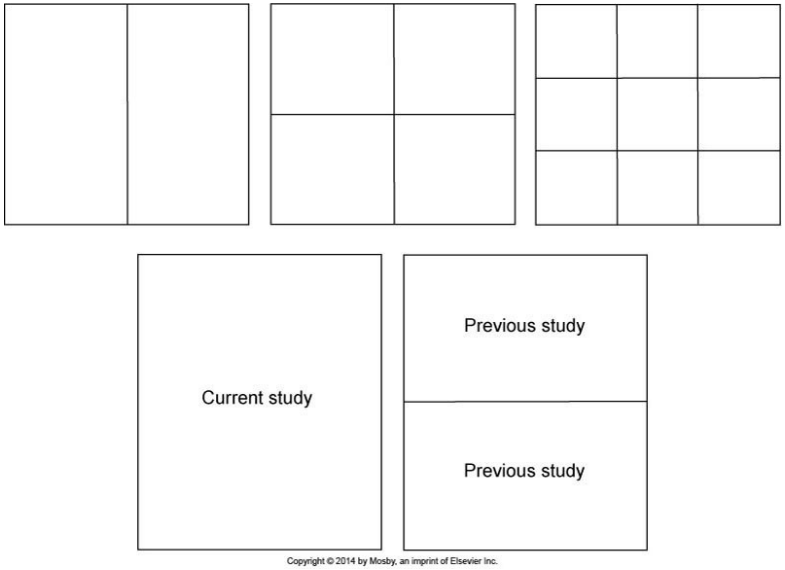
- Used for moving through images, studies and patients
- Worklist of all images/exams
  - Customizable for the user
  - Can select/deselect parameters
    - i.e. only CT exams performed today, only unread exams
  - Search parameters can be set



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Navigation Functions

- Hanging Protocols
  - Can customize how images will be displayed
  - Once patient has been selected from the worklist, the images are loaded into the display software
- Each user has the ability to customize how they want the image displayed
  - Can be different between modalities
- Can also set it to display previous studies with current studies



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Study Navigation

- Study is the current or previous examination being viewed
  - Can be a single image, multiple images or several series of images
  - Can page through the images with either the scroll wheel of the mouse or with arrows on the keyboard
  - Can also run through the stack, like a flipbook (cine – often for sectional imaging)
- Various icons for allowing user to move through studies, view previous, close current study

Image Manipulation

- When the image is displayed, many tools are available to manipulate the appearance of it
  - Window level/width
  - Annotations
  - Rotation
  - Magnification/Zoom/Pan
  - Measurements (Distance, angle, ROI)

Image Management

- Modification of Demographic information
  - Most workstations – tech, radiologist and fileroom station
  - Absolutely critical that this information is accurate
    - If the wrong information is attached to an image, it could be impossible to locate the image again
  - Changes should only be made when it is absolutely necessary and absolutely certain
  - To minimize errors, this function is often only allowed to certain users (superusers)

Image Management

- Query/Retrieve Function
  - Used to retrieve studies from the archive
  - Query – allows user to search using fields
    - i.e. pt name, ID number, exam type
- CD Burning
  - Allows users to save studies to a CD for future use
  - Usually the fileroom – this allows control of the CDs that are sent out (compliance with HIPAA)
- Printing
  - Laser printer
  - Usually only done in file room to maintain control (HIPAA)

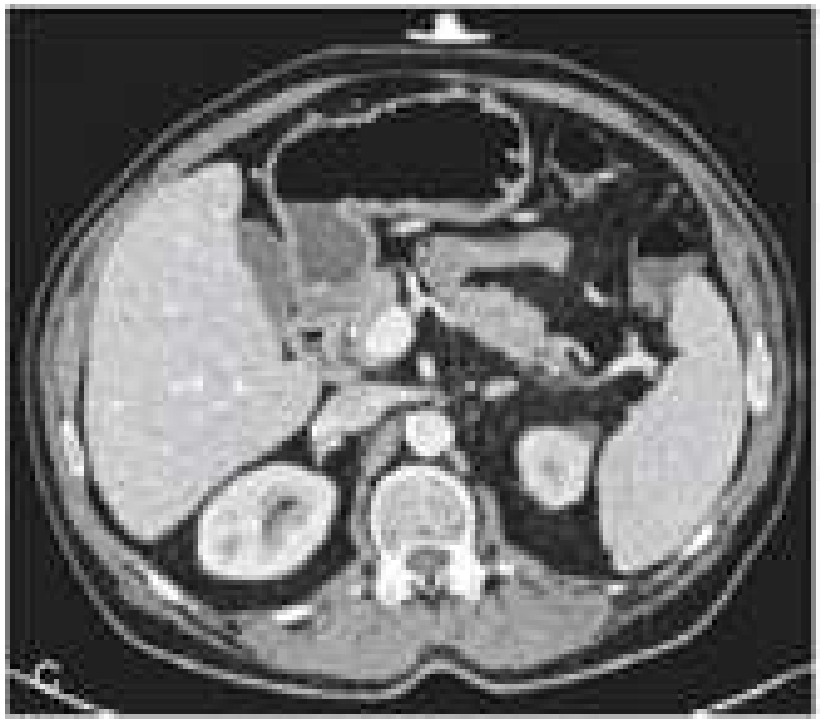
Advanced Workstation Functions

- Usually on the radiologist workstation, but some can be found on the tech's QC station
- Tech's QC Station Advanced Functions
  - Stitching, post processing (smoothing, edge enhancement)
- Common ones are:
  - Multiplanar Reconstruction (MPR)
  - Maximum and Minimum Intensity Projection (MIP and MinIp)
  - Volume Rendering Technique (VRT)
  - Shaded surface display (SSD)

Advanced Workstation Functions

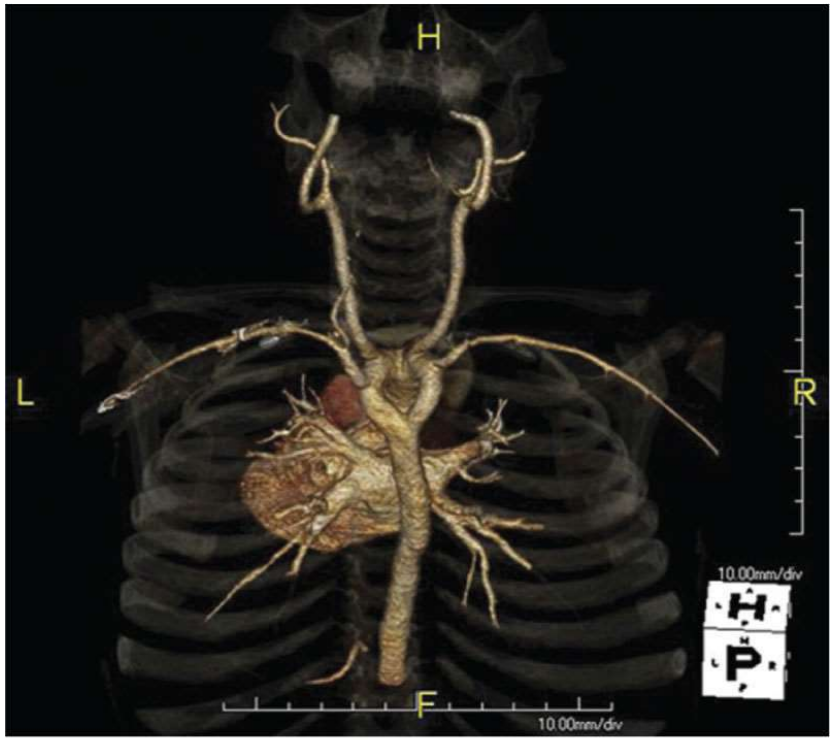
- Multiplanar Reconstruction
  - Most commonly used 3-D rendering techniques
  - When CT images are attained, the axial image slices are loaded into the software and reconstruction in another plane can be done without re-irradiating patient (ie coronal slices)
- Maximum and Minimum Intensity Projection
  - Used for visualizing vessels and air filled structures, often after contrast injection in CT/MRI

Multiplanar Reconstruction





Maximum Intensity Projection



Courtesy Lance Blackwell, TeraRecon, Inc.

Advanced Workstation Functions

- Volume Rendering Technique
  - Similar to MIP but user can assign colors to the different densities (tissue, contrast, air..etc)
- Shade Surface Display
  - Uses a range of pixel intensity values, everything below is removed, and everything above will be assigned a color and shown as a 3D object

Volume Rendering Technique



Courtesy Lance Blackwell, TeraRecon, Inc.

Shade Surface Display



Courtesy Lance Blackwell, TeraRecon, Inc.

PACS Archiving

- Electronic archive of PACS is like an file room and warehouse for all DICOM imaging modalities
- Stores all patient and image data
- Controls the receipt, storage and distribution of new and historic images
- Comprised of a complex arrangement of computers and storage space
- Can be divided into two categories:
  - Image manager
  - Image storage or archive server

Image Manager

- Contains the master database of everything that is in the archive
  - Receipt, retrieval and distribution of the images it stores
    - Image header information, not actual image data
  - Controls all the DICOM processes running within the archive
- This is the component of PACS that interfaces with HIS and RIS
  - allows the database to collect additional patient information
  - Also has a role in populating image information into the hospital electronic medical record (EMR)

Image Manager

- Runs a reliable commercial database (ie Oracle)
- Mirrored database – meaning two identical databases are running at the same time
  - If one fails, the system can call on the mirror and continue to run as normal (no downtime)
- Database contains only the image header information, not the image data
  - Pt name, ID number, exam date, etc…
  - Makes it easier for manager to quickly move through data
  - Database has pointers associated with each image on the archive server which links to the data fields within the database

Image Manager

- Process:
  - Order for imaging is entered into RIS
  - Images completed and sent to archive
  - Image manager extracts image header from each image and assigns a pointer to each image or series
  - Database files the information into various fields and communicates with RIS to verify info
  - When that study is queried, pointers locate the images on the archive server and send images to the workstation

Image Storage

- Image Storage or Archive Server
- This is the actual physical storage device of the archive system
- Usually consists of 2 or 3 tiers of storage
  - Short-term
    - Available within seconds
  - Mid-term (not always included)
  - Long-term
    - Images that must be retrieved from a device, could take 1-5 minutes

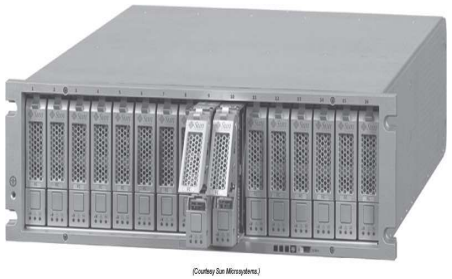


Short Term Storage

- Commonly a RAID (redundant array of independent disks)
- RAID is made of several magnetic disks or hard drives that are linked as an array
  - Size can range from several hundred GB to several TB
  - Capacity increases with technological advances
- RAID configurations divide or replicate data over multiple hard drives
- Drives are designed to work together and appear to the computer as one single storage device

RAID levels

- Several levels of RAID
- Expands to 11 levels, mostly different combinations of the first 5 levels
- 4 levels most commonly used are RAID 0, 1, 3 and 5
- Most PACS archives will use RAID 5



(Courtesy Sun Microsystems.)



(Courtesy Sun Microsystems.)



Long Term Storage

- RAID commonly used also
- Other products are:
- Optical disk
- Tape
  - These use a jukebox to hold the tapes/disks
- Magnetic disk
  - Uses an array



Optical Disks

- Magneto-optical Disk (MOD)
  - Similar to a CD or DVD, but is housed in a plastic cartridge
  - Reliable, robust – can handle years of reading
  - Cost a bit higher per gigabyte
- Digital Versatile Disk (DVD)
  - Higher capacity than CDs
  - Least expensive method – per gigabyte
- Ultra Density Optical
  - New generation MOD
  - High capacity, comparable with DVDs

MOD and UDO

MOD

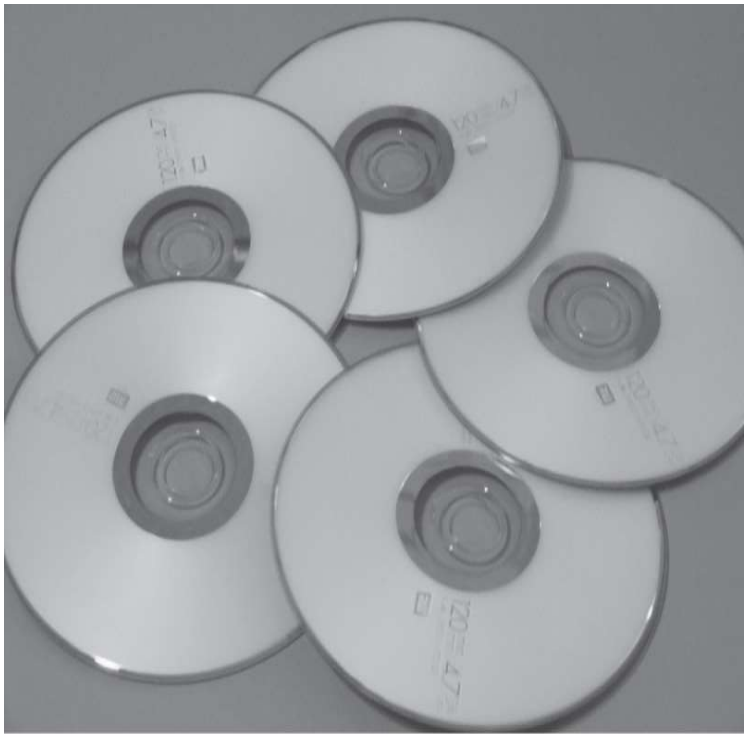


(Courtesy Plasmon.)

UDO



Disks and Jukebox



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(Courtesy IBM.)



Tape

- Tape libraries provide greatest scalability- can continually grow and expand storage limits
  - Can add libraries onto original
- Low cost medium, various sizes
- Tapes are contained within a jukebox with multiple drives
  - Can have 10-1448 tapes in one library
  - Robot arm moves tapes in and out of the drives

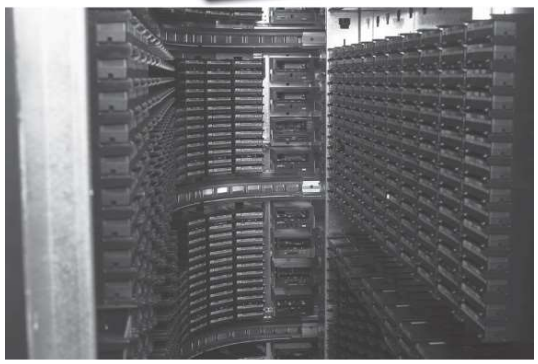
Tape

- Main disadvantage is that over multiple uses, it can become unreliable
  - Can wear out with heavy use and become damaged
- Longer access time compared to the optical disks
- Improvements being made for durability and speed



Tape Library





(Courtesy Sun Microsystems.)

Magnetic Disk

- As the price of magnetic disk storage comes down, RAID storage is becoming more feasible
- RAID arrays can be configured into:
  - DAS
    - Direct attached storage
  - NAS
    - Network attached storage
  - SAN
    - Storage area network



(Courtesy Sun Microsystems.)

Image Compression

- Reduction in the size of the image information to be stored without degrading the image quality to an unacceptable level
- Helps to save on storage space
- Two primary methods of image compression
  - Lossy
    - Reduces storage by eliminating some information
    - Not diagnostic quality – 'conversational' quality
  - Lossless
    - Exact replica of the original

PACS Peripheral Devices

- Film Digitizers can be used to scan analog films and produce a digital image
- Two main types:
- Laser Film Digitizer
  - Considered gold standard
  - Cons:
    - Expensive, maintenance
    - Quality control is critical
- CCD Film Digitizer
  - Less expensive than laser digitizer, but slower
  - Can have issues with extreme light/dark areas



(Courtesy Vidar, Herndon, VA)

Why are Digitizers Needed?

- Teleradiology
  - Allows radiologist to read from any location
- Comparison
  - Comparing film image with PACS image
  - Outside films vs current films
- Duplication
  - Sometimes hard copy is required, digitize film and print a copy on an imager
  - I.e travelling out of country
- Computer Aided Diagnosis (CAD)
  - New technology in mammography
  - Computer analyzes image for densities and alerts radiologist

Imagers

- Film Printers – printing off digital images
- Two major types:
  - Wet Imager
    - Uses chemicals to process the film
    - Needs darkroom, well ventilated area
    - Less popular due to having more requirements
  - Dry laser imager
    - Uses heat to process film
    - Exposed with laser
    - Quality slightly lower as compared to wet imager
    - Takes up less space, no special location needed
    - Only requires an outlet, very convenient to use



(Courtesy Eastman Kodak Co., Rochester, NY.)

Why are Imagers Needed?

- Backup if PACS unavailable
  - In case PACS goes down or unavailable in the area
  - i.e. OR suites where there is not enough space for a workstation
- Outside Physicians
  - Referring dr may want to see images while reading report
- Legal cases
- Teaching purposes

CD/DVD Burners

- Printing films can be costly, as laser film is a lot more expensive than conventional film
- Try to reduce printing, but burning images to an optical disk
  - Less expensive, and can have multiple studies on one disk
- Images can be burned onto a CD/DVD for the purpose of sharing outside of PACS
  - A DICOM viewer is also burned onto the disk so that the images can be displayed
  - Minor image enhancements will be possible
    - Windowing, measurements

Readings

- Digital Radiography and PACS 3rd Edition
  - Chapter 8
  - Chapter 9
  - Chapter 10
- Radiologic Science for Technologists 11th Ed
  - Pg 274-281, 329-332