CD-Based Image Archival and Management on a Hybrid Radiology Intranet

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This article describes the design and implementation of a low-cost image archival and management solution on a radiology network consisting of UNIX, IBM personal computer-compatible (IBM, Purchase, NY) and Macintosh (Apple Computer, Cupertino, CA) workstations. The picture archiving and communications system (PACS) is modular, scaleable and conforms to the Digital Imaging and Communications in Medicine (DICOM) 3.0 standard for image transfer, storage and retrieval. Image data is made available on soft-copy reporting workstations by a work-flow management scheme and on desktop computers through a World Wide Web (WWW) interface. Data archival is based on recordable compact disc (CD) technology and is automated. The project has allowed the radiology department to eliminate the use of film in magnetic resonance (MR) imaging, computed tomography (CT) and ultrasonography.

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KEY WORDS: PACS, recordable CD, image archival, DICOM 3.0, filmless radiology.

THE MONTREAL General Hospital is a 600-bed teaching facility that forms part of the McGill University Hospital Community. The hospital's Department of Diagnostic Radiology averages 160,000 examinations per year in conventional Radiography, angiography, mammography, magnetic resonance (MR) imaging, computed tomography (CT), and ultrasonography.

Based on the success of a filmless picture archiving and communication system (PACS) in our ultrasonography department that was developed in-house (see companion article on pages 80-82 in this issue¹), MR imaging and CT were chosen as the next targets for our image management project. Whereas the ultrasound system consisted of Apple Macintosh computers (Apple Computer, Cupertino, CA) and a Sun SPARCstation (Sun Microsystems, Mountain View, CA) server

connected by a local area network (LAN) using the Appletalk protocol, the decision was made to direct further PACS development towards supporting the DICOM 3.0 standard.

DESIGN

The resulting system uses a modular client/server design with multiple specialized servers that run custom software and scripts to fulfill designated tasks. Figure 1 illustrates the flow of images and data among the various components of the PACS.

Wherever possible, we used off-the-shelf hardware and freely available software combined with in-house design, development, and implementation. The rationale for this approach was based partly on financial limitations, but had the attraction of allowing the design to be customized and supported in-house, and adapted to the changing needs of the users.

The Network

The system was built on an existing hybrid departmental LAN that supports Appletalk, Novell IPX/SPX, and TCP/IP protocols. Two Ethernet switches were added to the network to allow segmentation into workgroups. Modality workgroups consist of one or more scanners, a modality server (for short-term data storage), and related reporting workstations. These specialized segments support only TCP/IP and are designed to localize network traffic. Other workgroups are multiprotocol and consist of UNIX, Macintosh, and PC-compatible desktop computers, workstations, file servers, and printers.

Image Viewing and Reporting

Reporting is carried out on high-end GE Phoenix workstations (GE Medical Systems, Canada) with dual monitors running Advantage Review software. Work-flow management is achieved by automatically routing images from each modality server to the appropriate workstation(s). Scrapbooks (single series collections of clinically significant, annotated images) are prepared for each case and returned to the modality server. They later are archived with the study and become available for clinical review, paper print, download, or teaching.

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0897-1889/97/1003-1054\$3.00/0*

Fig 1. Image data flow and database transactions among components of the PACS.

Clinical review is available by a variety of means that include access for download or viewing through a World Wide Web (WWW) interface, viewing on one of two GE Advantage Remote Review workstations, or by printing on plain paper.

Archive Media

Compact disk recordable (CD-R) technology was chosen as the media for archiving because it offers a balance between robustness, cost, portability, and ease of data access. The main drawback of CD-R is the requirement for batch-mode recording of CDs. This was overcome by designing an archival server to which a copy of all images are routed automatically, then sorted by study and modality, catalogued, and stored in CD-sized spools that are then written to the CD.

IMPLEMENTATION

Modality Server

The modality server interacts with its associated scanners and workstations in the modality suite, and supports the DICOM Storage and Query/Retrieve service classes as both provider (SCP) and user (SCU).² Images are sent automatically by the scanners to the appropriate modality server where they are stored on disk and entered in a local database. Entries subsequently are made in a remote master database to keep track of the location of every study on the network.

The modality server manages work-flow by routing incoming images automatically to a set of predefined locations, typically the primary reporting workstations, a teleradiology server, and an archive server, using criteria such as modality and study description. This task is run independently from image storage through the use of a routing

database. Each record in the database represents an image that has been received on the modality server and may require routing. Using a set of rules, the router first annotates each entry with a list of destinations, then attempts transmission. Each image/destination pair is recorded to disk and deleted once it has been transferred successfully.

As well, users can access the modality server directly to view patient listings and transfer studies to their workstations. This provides an alternative to the work-flow management scheme should studies be required on workstations other than those to which they were routed automatically.

Each modality server provides 6 to 8 weeks of on-line data storage using three 9-gigabyte (GB) hard drives. The server automatically monitors this storage and deletes the oldest data when capacity is reached. Records of deleted studies are removed from the local image database and modified in the master database to indicate that they are no longer available in primary storage.

Database Server

The database server maintains a complete record of all studies performed in CT, MR imaging, and ultrasonography in a master database (MDB). This database is similar to the local image databases on the modality servers, but contains only patient, study, and series level records. As well, the MDB has a table that lists the location(s) of any given study on the network. This table is used by other applications to perform transfers as efficiently as possible.

An HL-7 gateway, currently in development, will connect the master database server to the hospital's mainframe hospital information system (HIS), allowing orders and reports to be exchanged with a radiological information system (RIS) that is also being developed. Ultimately, this will allow reports to be made available with images via a WWW interface.

Archival Server

The archival server consists of a CD-R unit, a digital audio tape (DAT) drive, and one 9-GB drive for temporary spooling of incoming image data. All scanned images from the digital modalities are routed automatically from modality servers to the archival server where they are sorted by modality and spooled in CD-sized directories. When a directory approaches the CD limit of 680 MB, it is

flagged by the server and locked after all in-progress studies have been received. The server then writes the contents of the directory to a CD and appends the same data to tape for redundant data storage. After the recording process is complete, the server verifies the CD against the original data set. This entire process is fully automated, only requiring periodic insertion of blank CDs. The CD is then sent to the main filing room for storage until needed for retrieval of off-line studies.

Teleradiology Server

The teleradiology server hosts the WWW interface to our PACS (see companion article in this issue³). Using a WWW browser such as *Netscape* (Netscape Communications Corp, Mountain View, CA) or *Microsoft Internet Explorer* (Microsoft Corp, Redmond, WA), users gain quick access to the entire image network through the master database. As well, the teleradiology server acts as a DICOM Storage SCP for images routed to it by the modality servers.

Incoming images are converted to JPEG format for viewing in the web browser, and a DICOM part 10⁴ format for downloading to the local disk. Files are stored on a single 9-GB hard disk, and their location is entered in a local database. When the disk nears capacity, the oldest studies are deleted from both disk and database.

Retrieval Server

The retrieval server coordinates the process of restoring studies from a CD for redistribution on the network or printing on plain paper. The server continuously monitors a request queue and runs an application used by the film clerks to pre-fetch studies and respond to CD requests. When a request is received, the server determines the CD required and prompts the clerk to insert it in the CD-ROM drive. If the study is being pre-fetched, the images are routed automatically to the appropriate reporting workstation(s). All other retrieval requests

include a user-specified destination. Printing requests are handled directly from the CD and sent to a user-specified printer.

DISCUSSION

Data Redundancy

Once an image is transmitted from the scanner it can be found in some form in at least four locations on the network: the associated modality server, the archival server, the teleradiology server, and at least one reporting workstation. The cost is an increase in network traffic but, by localizing most traffic to workgroups, the effect on the entire network is minimized.

Security

Security issues have been addressed in several ways. The DICOM 3.0 compliant systems use the *Association* class to authenticate each SCU. This prevents unauthorized hosts from accessing scanners or servers directly via the DICOM protocol. The teleradiology server uses both host-level security and username-password authentication available in the WWW server. We realize, however, that this level of security is inadequate when a PACS network is connected to the Internet. Therefore, we have added a "firewall" to our network to more tightly control outside access.

CONCLUSIONS

Films now have been eliminated entirely in CT and MR imaging, and ultrasonography has been filmless for almost 2 years. Using specialized servers and high-quality reporting workstations combined with work-flow management and ready access to images, we have implemented a PACS that can accommodate future expansion. By using a modular design, we have distributed network traffic and computational burdens evenly over inexpensive hardware in a cohesive manner. The resulting system forms a basis for filmless image management and is a model for low-cost PACS development.

REFERENCES

1. Henri CJ, Cox RD, Bret PM: Implementation of a filmless ultrasound mini-PACS: Experience after one year of use. Presented at the 14th Symposium for Computer Applications in Radiology. 1997. *J Digit Imaging* 10 (Suppl 1): 80-82, 1997
2. Moore SM, Hoffman SA, Beecher DE: DICOM shareware: A public implementation of the DICOM standard, in Jost RG (ed): *Medical Imaging 1994-PACS: Design and Evaluation*, volume 2165, pages 772-781. SPIE, 1994
3. Henri CJ, Cox RD, Rubin R, et al: Design and implementation of WWW-based tools for image management in CT, MRI and ultrasound. Presented at the 14th Symposium for Computer Applications in Radiology. 1997. *J Digit Imaging* 10 (Suppl 1): 77-79, 1997
4. Ratib O, Hoehn H, Girard C, et al: Papyrus 3.0: DICOM compatible file format. *Med Inform* 19:171-178, 1994