Automated Routing of DICOM CT, MR, and CR Images: Solving the Pitfalls of Vendor-Specific DICOM Implementations

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This paper details our experience in developing and implementing an automated DICOM Image Router. This workstation serves as a gateway between image acquisition devices and image display and storage devices. Images are checked for demographic input errors and data format inconsistencies between the source and destination devices. Based on the configured rules, an image may be held for manual correction and/or distributed to multiple locations. Distribution is based upon easily configured environmental variables and rules files which may be changed as needed. For example, CT images are typically sent to the archive and to a radiologist's display workstation. If the patient came from the Emergency Department, a copy of the images are sent to a clinician display workstation located in the Emergency Department. If the patient has suffered trauma to the head, a copy of the images are sent to a display workstation in the Neurosurgery Department for possible consultation. The software was developed on a UNIX-based platform and utilizes a Fast Ethernet network. To date, images from a variety of devices have been acquired: General Electric HiSpeed CT/I scanner, General Electric Signa MRI scanner, Philips Thoravision Digital Chest unit, and Fuji AC-3CS Computed Radiography (CR) unit. Each device has presented new challenges in providing a uniform look to patient demographics in the PACS archive. The workstation also provides a buffer in the event of network outages, storing images for later transmission when the network and/or a workstation recover.

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AS IMAGE ACQUISITION devices were upgraded at our institution to utilize Digital Imaging and Communication in Medicine (DICOM) 3.0 protocols, the need quickly arose for an automated means of image distribution to multiple image display and storage devices. A workstation that serves as a gateway between these image sources and destinations has been developed and implemented. Distribution of images is directed by environmental variables and rules files which may be easily changed. This distribution is configured based upon the imaging modality as well as patient location.

In addition to image routing, this workstation has provided the capability to solve many other critical issues such as: an automated verification check for input errors of patient demographics; a user interface for correction of demographic input errors; temporary storage of unsent images during device

or network outages; and specialized filtering of demographic information. Five of these Image Routing workstations have currently been deployed throughout our institution.

METHODS AND MATERIALS

Software for this workstation was developed using the C programming language and Perl scripting language. Software to provide DICOM Storage Class Service Class User and Provider was developed using the ACR-NEMA Application Programmer's Interface (AN/API) library (DeJarnette Research Systems, Towson, MD). The hardware platform used has been from the Sun family of UNIX workstations, in particular: the Sparcclassic, Sparcstation 5, and UltraSparc 170E (Sun Microsystems Inc., Palo Alto, CA). Networking capability has also ranged from shared 10BaseT to switched 100BaseT Ethernet as the institution's network has been upgraded.

Issues and Features

The processing of an image is shown schematically in Fig 1. Upon reception by the workstation an image is first verified and then sent. The partitioning of disk space on the workstation for the storage of images also follows Fig 1. An image's location on disk reveals the status of its processing. In the event of database corruption or system downtime, normal operations can therefore be quickly restored.

Each image that is received by the workstation is stored on disk with a filename corresponding to the Service Object Pair Instance Unique Identifier (SOP Instance UID, DICOM tag 0x0008, 0x0018) of the image. For a DICOM compliant image acquisition system, this UID is guaranteed to be unique thereby eliminating the possibility that files can be overwritten and information lost.

A verification step is next performed on the demographic data in the DICOM image header. The three items of information that are currently verified are: Patient's Name, Patient ID, and Accession Number. For each item a series of rules must be satisfied. For example in the case of the Patient Name: length of name must be greater than 4 characters; no digits can be present; no special characters such as , [] ; patient last name cannot be DOE; no lower case characters can be present. If any of these rules fails the image is unverified. The demographic information is stored in a database and the image is placed in a separate disk partition for manual intervention.

Distribution of a verified image can be determined by a number of factors. All images are stored in a central archive so the list of receivers begins with the archive. Additional receivers are next added to the receiver list based upon the image modality

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Fig 1. Information flow diagram for the processing of a DICOM image.

(eg, CT, MR, CR). Finally additional receivers are added based upon keywords placed by the technologist during entry of demographic information. For example in our CT scanners these keywords are entered into the Study Description (DICOM tag 0×0008, 0×1030). These keywords may be based upon patient location such as the phrase UED for an Emergency Department patient. This allows for the transmission only of relevant CT images to an image viewing workstation located in the Emergency Department. The keyword may be based upon the service having primary responsibility for the patient. At our institution, several hospital services such as Neurosurgery, Orthopedics, and Otolaryngology have specialized systems capable of receiving DICOM images to assist them in treatment and surgery planning.

A separate list of receivers is maintained for unverified images. In the case of Emergency Department CR images the image needs to be available at the clinician's viewing station as quickly as possible with whatever information is available at the time. For example a patient name of Alpha Doe in an unverified image is still relevant information to the Emergency Department clinician. However before archiving of the verified image the correct patient name must be determined.

Once the list of receivers is determined, the image is sent to each receiver. A UNIX ping command tests the network connection between source and receiver before an attempt is made. If the image is not successfully sent to a receiver, a database entry is made and the image is stored in a separate disk partition. Periodically an attempt is made to resend all images in this unsent partition.

An image which is successfully sent to all receivers is stored on disk and compressed using a standard UNIX compression utility. As the disk partition containing these images fills, old images are automatically removed from the disk.

A graphical user interface is used to provide the technologist with a means to correct the demographic data of unverified images. This code is written in C with the XView Application Programmer's Interface toolkit. The Patient Name, Patient ID, and Accession Number fields may be edited. For multiple image exams such as CT and MR, changes made to the demographic

data of one image are propagated through the entire exam. Once an image is edited it is passed through the verification procedure once again, and if verified can be sent to the appropriate receivers.

Additional specialized filtering can be done to solve a myriad of problems that have presented themselves due to specific vendor implementations of DICOM or through inadequacies in user interfaces. In several areas of our institution, images are viewed on a workstation having a user interface for which the Accession Number display is fixed to a maximum of 6 digits. At our institution the Accession Number is currently 7 digits long and when displayed on this vendor-purchased workstation would have the least significant digit truncated. Therefore two separate exams for a patient would appear as duplicate entries with the same Accession Number (for example Accession Numbers 1234567 and 1234568 would both appear as 123456). For each image receiver in our system, a parameter file is located on the workstation containing the necessary parameters for making a DICOM Association (IP address, Application Entity title, and Port Number). To alleviate this problem, a special flag was added to this parameter set. For other image receivers the Accession Number is left unchanged. However for these viewing workstations a special flag value is used to indicate that the most significant digit of the Accession Number is to be eliminated before sending the image. For example images with Accession Numbers 1234567 and 1234568 would be sent only to these workstations with an Accession Number of 234567 and 234568 respectively.

Another problem that has been eliminated through the use of the image routing workstation involved user interface software used in our CT and MR scanners. This software had no field in which the technologist could enter an Accession Number as a part of the patient demographic information. Instead the technologist was instructed to place the Accession Number at the beginning of the Referring Physician field (DICOM tag 0×0008, 0×0090). The workstation recognized images coming from these image sources and copied the 7 digits from the beginning of the Referring Physician field into the Accession Number field before distributing them to the receivers.

Various imaging modalities will pad the Accession Number and Patient ID with leading zeros to provide a fixed field length. In the viewing workstations used at our institution, the default mode of querying an archive by Patient ID required that the ID entered by the user match precisely with the ID of the stored image. Therefore an image belonging to patient 00123456 would not appear in a response to a query for images belonging to patient 123456. By eliminating leading zeros from all images going to the archive, this problem is alleviated.

RESULTS

For large images such as CR, the majority of time spent processing an image by the workstation is in the distribution of the image over the network. Although many factors are involved in determining network throughput, Table 1 gives average performance values for the sending of 10 MB CR images. The Local Area Network (LAN) in use at our institution utilizes packet-switching and asynchronous transfer mode (ATM). One benefit of this

Table 1. Time to Transmit a 10 MB CR Image from Two Different Source Computers to the Same Destination. The Destination Computer is a 167 MHz UltraSparc. Local Refers to the Same Subnet While Remote Involves a Separate Subnet on the ATM Backbone

Network	Time to Transmit (s) from 167 MHz UltraSparc	Time to Transmit (s) from 110 MHz Sparc5
Local 100 BaseT	5	8
Remote 100 BaseT	5	9
Remote 10 BaseT	13	18

technology is that image transfer time is not degraded by physical distance on the LAN. Thus in Table 1 the time to transmit an image to a local receiver is the same as the time to transmit an image to a receiver located in a different part of the LAN. Also we see a factor of 2 to 3 increase in performance by utilizing Fast Ethernet (100 BaseT) as opposed to standard Ethernet (10 BaseT).

As described previously, the Image Routing workstation has two main functions: to distribute images to multiple locations, and to allow for correction of patient demographic information. This second function has dictated that we place the workstation physically close to the source of images it is receiving in order to allow the technologist performing the examination easy access to correct unverified images. Table 2 shows the vol-

Table 2. Image Volume Received by the Five Image Routing Workstations and Number of Receivers That These Images Are Typically Sent To

Image Type	# Images Per Day	# GB Per Day	# Receivers
CR	245	2.4	4
CR	74	0.65	2
CT	1817	0.44	2
CT	1978	0.48	2
MRI	2516	0.31	1

ume of images handled by each of the five Image Routing workstations that have been deployed. The software has the capability to handle any image type, but due to their physical locations each workstation has been predominantly receiving only one type of image for processing.

CONCLUSIONS

A workstation has been designed and implemented to automatically route DICOM CT, CR, and MR images to a variety of display and storage devices. The workstation is also capable of alleviating problems due to inadequacies in vendor implementations of DICOM and in user interface software. The automated verification of patient demographic data has proven to be a very useful quality control tool in eliminating erroneous or incomplete information.