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Implementation of a Low-Cost PACS/CR for Clinical Use in Yonsei Cardiovascular Center

Jae Man Huh[a], Sun Kook Yoo[b], Nam Hyun Kim[b], Byung Chul Chang[a], Do Yun Lee[c], Bum Koo Cho[a], Soo Hyun Bae[b], Kwang Min Kim[b], Eun Jung Kim[b], Gyoung Duck Kim[d]

[a]*Cardiovascular Research Institute, Yonsei University College of Medicine, Seoul, Korea*
[b]*Department of Medical Engineering, Yonsei University College of Medicine, Seoul, Korea*
[c]*Department of Diagnostic Radiology, Yonsei University College of Medicine, Seoul, Korea*
[d]*Department of Information Technology, Yonsei Medical Center, Seoul, Korea*

Abstract

The PACS/CR for clinical use in Yonsei Cardiovascular Center has been designed and implemented. Our system is open architecture to comply with emerging standards such as DICOM, database SQL, TCP/IP and to reduce operational and maintenance costs, PC-based low cost workstations running Microsoft Windows, database as Microsoft SQL based on Client/Server, Long-term storage using CD-ROM Jukebox are developed. Also, auto routing and image pre-fetching are implemented.

Keywords

PACS/CR; DICOM; SQL database; TCP/IP; Open Architecture; Client/Server, .

Introduction

In Yonsei Cardiovascular Center (YCC), x-ray images usually are used in diagnosis. As digital imaging becomes more important in radiology practice, the need to convert images from projection radiography into digital format becomes apparent. Computed Radiography (CR), as one of the major digital radiography methods, aims to replace screen/film radiographs and is becoming more widely used in medical centers [1].

Our center purchased computed radiography (two FCR AC3) in 1996. After that, we have designed a PACS/CR for clinical use in Radiology, ICU, CCU and wards. The goal of this system is to better serve each site by providing fast, reliable access to X-ray image data from viewing stations instead of film. Film production, distribution, and storage for each site will be replaced by networked image delivery, interpretation via soft-copy display, and archive to CD-ROM.

One of our utmost design criteria is to ensure consistent delivery of high speed and high performance image throughput, and yet, the system should be cost-effective and maintained with minimum costs.

Materials and Methods

CR Image Throughput

Our Center has two CR systems (Fuji AC3) and performs approximately 38,880 inpatient and outpatient imaging examination each year. About 36,400 of those are chest exams, of which about 14,500 are performed at the bedside. Table 1 summarizes total CR image output in YCC.

Table 1 - Yearly CR Image Output in YCC

Region	In-patient	Out-patient	Total /year	Gbytes
Skull	20		.20	0.16
Chest	22,000	14,400	36,400	1
Abdomen	1,700	40	1,740	13.92
Spine	420	90	510	4.08
Extremity	100	110	220	1.76
Total Images/ year	24,200	14,640	38,880	310

The design concept of PACS/CR at YCC is based on standardization and open architecture. Open architecture design means that all application software programs are portable. Any change in hardware platform or software operating system requires only the development of an adapter (software layer) between the existing application software and the new platform or the operating system while the application software remains intact.[2]

Design Criteria

The PACS/CR system designed in this study is shown in Figure 1. Both the client and server are designed according to the ISO OSI model with the layers as DICOM 3.0, TCP/IP and Fast Ethernet. Designing for a low-cost PACS/CR in YCC, we use commercially available hardware and software technologies to comply with emerging standards(e.g., DICOM, database SQL, TCP/IP). And we also maximize COST use to reduce operational and maintenance costs.

Image Acquisition

The YCC PACS/CR connects two FCR AC3 systems. The digital interface to PACS uses DMS Bus with a RS-485 cable(which is a combination of RS232 serial bus for message and textual information and a RS-422 parallel bus for image data) connection to the data acquisition system manager(DASM). The DASM is basically a ring-buffered SCSI disk which transmits both textual and images data from the CR

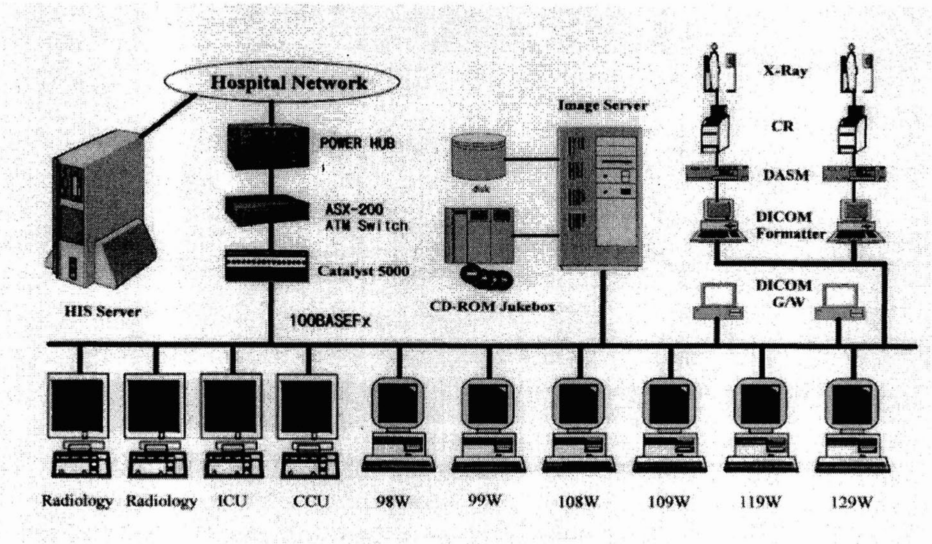

Figure 1 - YCC PACS/CR System Concept

to the SUN acquisition computer over SCSI cable. As the SUN acquisition computer, we use Dejarnette Gateway that converts the image header from Fuji proprietary format to the standardized DICOM 3.0 format and transmits the DICOM 3.0 Data to the external terminal over TCP/IP.

In this study, we designed a DICOM interface unit (DIU) based on PC-586 over Ethernet (10baseT) using TCP/IP to receive the DICOM image output from the Dejarnette gateway and store it in our designed image server. In this unit, we use DICOM upper layer protocol based on TCP/IP. The DIU is programmed in stream socket method over TCP/IP protocol using windows socket version 1.1 that connects Microsoft windows and the network programming interface. Before storing the acquired CR image to the server, the DIU connects the HIS server to receive a Korean patient name because FCR only deals with English patient names. This is important in the domestic environment because the physicians query the image using the Korean name key frequently instead of patient ID. The data flow and processing steps in image acquisition is shown in Figure 2.

Image Workstation

Given a low cost, end-user graphical interface and accessibility, it is desirable to implement image workstation on a personal computer rather than a workstation platform. We design image workstation based on a 200 MHz Pentium PC with 64 Mbyte RAM and 2 Gbyte hard drive. Also, because the main cost of image workstation is due to display monitors (above 6,000 US$ each), we adopt two types of monitors. For the Radiology, ICU and CCU, we use Data Ray/DR90 as the display monitor and DOME Graphic card as controller which has 1280x1600 pixel units. And, for the wards, we use Microscan 17X pivoting color display monitor with 1280x1024 pixel units made by Taiwan. (lower than 1,000US$) Each image display consists of one portrait monitor. Therefore, we developed image workstation for wards for less than 3,000 US$.

The software is designed to allow unified customization of diverse image processing functions, systematic extension of hardware components and easy graphical interface for non-computer oriented medical personnel. An object oriented approach is employed by using the object oriented programming language Visual C++ 4.2 under the WINDOW'95 environment. The user interface is graphical and is displayed on the same monitor. The user of the workstation can invoke all images selection and manipulation functions from this soft control panel using a two-button mouse. It supports basic high performance image display, manipulation and annotation.

Image Storage and Database

The image server was designed to be used in a clustered or mini-PACS environment.[3,4] This clustered approach has the advantage of being very scaleable and modular. The system may start with one server and grow to many servers. Performance can be maintained with good network design.[5]

We have only one image server for CR, which is COMPAQ Proliant with 64 GB RAID (mirrored database). The storage management system for image display features three levels of user-accessible storage media:

- hard disks in the display station for local storage to immediate access for few days images
- RAID in the image server for the short-term storage(within one month) to retrieve fast via 100 Mbps dedicated network system
- CD-ROM jukebox for the long-term storage to retrieve any historical CR images

In the image database, we designed relation table using Microsoft SQL 6.0 to index the stored CR images. Images load from the image server in workstation is done using ODBC(Open

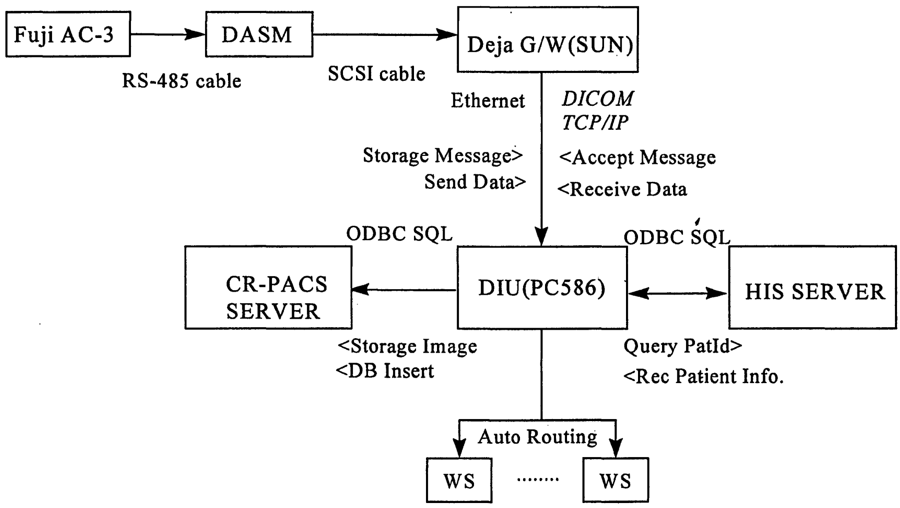

Figure 2 - Data flow and processing steps in image acquisition

Database Connection) SQL. ODBC is the database portion of the Microsoft Windows Open Services Architecture (WOSA), an interface which allows Windows-based desktop applications to connect to multiple computing environments without rewriting the application for each platform.[6]

Image Network

There are two digital networks in the YCC PACS/CR. Ethernet (10baseT) is used to connect the Dejarnette DICOM gateway (SUN SPARK 5) to DIU. After receiving the CR image from DASM via RS422, the DICOM gateway reformats it to a DICOM image and delivers it to the external computer using TCP/IP over the network. Another dedicated network is fast Ethernet with 100 Mbps, which is used to transfer images from image server to the workstation.

Image Auto-Routing and Prefetching

Because our system uses three levels of storage media, auto-routing and pre-fetching of images are very important to support workflow in clinical use.

For auto routing, the PACS receives information about the place where the patient is hospitalized and other information about the patient status from the HIS server. A routing process then decides where to auto-route the images from the image server to each workstation.

In pre-fetching of images, all previous images of the patient from the archive of CD-ROM jukebox are pre-fetched based on the administrative information received from the HIS server.

HIS/PACS Interface

There are three main reasons to interface the HIS to the PACS system. The first and second are for auto-routing and pre-fetching of images. The last is for data consistency. Especially, data consistency is very important because most PACS and HIS struggle with the insufficient identification of patients.[7] In countries where the native language is not English like Korea, data for the same patient is often stored under several names because of the multiple manual data entry in the different systems. For example, a patient may exist with slightly different names (like “kildong”, “gildong”, “keeldong”, “geeldong”) due to incorrect spelling. To avoid this problem, by using a unique identification number of our hospital, the English name only is used in modalities and sent through the HIS/PACS interface without repeated manual data entry. The Korean name is used for the storage in the image server and for query in the viewing workstation.

In HIS/PACS interfacing, currently we use proprietary data format based on ODBC SQL between two systems because the HIS has been developed by our team, and we don’t adopt standard interfaces (HL7, DICOM) yet.

Results

A design and implementation of PACS/CR in YCC has been presented. The objective of this project is to better serve ICU, CCU and each ward in Yonsei Cardiovascular Center by providing fast, reliable access to X-ray image data from viewing stations. The design is based on an open architecture to comply with emerging standards such as DICOM, database SQL, TCP/IP, and also based on the existing PACS components commercially available.

We developed PC-based low cost clinical workstation priced at about 3,000$(US). An independent DICOM-based PACS is successfully running with 11 workstations. Rules-based workflow management routes the exams to their destinations (Workstations, Archive), and CR exam is displayed within 3 seconds in the workstation.

In the future, proprietary interface between the systems will be replaced by standard interfaces (HL7, DICOM) after our HIS will be replaced by a new system to support these standard protocols. Also, because the department of radiology in our main hospital is currently constructing the mini-PACS which connects multi-modalities such as CT, MR, EBT and angiography by purchasing the Loral PACS(now GE PACS), we will interface these two heterogeneous PACSs based on DICOM gateway.

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