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Implementation of Web-based Management System for Pacs Network

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Abstract

The main strategy of this paper is to Construct picture archiving and communication system (PACS) for hospitals that provides electronic requesting, delivering, reporting, storing, and retrieving the medical images and associated data from medical modalities such as X-Ray, CT and MRI. The design and implementation of Web-based management system for PACS network were achieved at the university labs including the necessary interfaces (HIS/RIS interfaces) that feed the pertinent data to the PACS like demographic information, patient history, examination orders, etc. The project was implemented into number of subsystems that perform the essential functions of the PACS software. Each subsystem is accessed by a group of members who are part of the patient workflow in the hospital system and this access is restricted through user identification and authentication technique. However the complete structure of the system is a modular one consisting of numbers of the pluggable modules that allow adding new features by coding them as separate modules and plugging them into the existing system. This makes the project flexible and applicable. The open source platforms (Apache Web server, MySQL database server, Filezilla FTP server, and PHP server-side scripting) were used for their security, reliability, robust, and support community.

Keywords

PACS; HIS; RIS; MIS; Information Management System; DICOM; HL7

Introduction

PACS is a medical information system designed to acquire, move, store and display digital images from medical modalities such as X-ray, CT, and MRI on the computer screen rather than hard films. It enables many hospitals around the world to organize and distribute their radiology images (Robert Reuben Wooldridge,2008) and represents a powerful tool for improving patient care by improving diagnostic accuracy, decreasing lost films and increasing the speed of patient turnaround (Alberto Pastrana Palma, 2010). Compared with the film based radiology system, the PACS has a great multitude of advantages, e.g., easier distribution of images at enterprise level, much shorter image transmission time, simpler archival management with less storage space and personnel, more flexible image manipulation, improved training of residents and students, and easier image copying and backup (Peng Zhou, 2008). PACS as any other information system requires pertinent data from other medical information systems. Among these systems, data from the hospital information system (HIS) and radiology information system (RIS) are of most importance (H. K. Huang, 2004).

RIS is used in the radiology department for tracking and managing patient's films (Alberto Pastrana Palma, 2010). While the HIS is typically the official repository for the entire patient's records, including the radiology records from the RIS, as well as laboratory results and other patient health information (Robert Reuben Wooldridge, 2008). It is used for administrating hospital and managing clinical processes (Alberto Pastrana Palma, 2010). RIS and HIS information such as clinical diagnosis, radiological reports, and patient history are necessary at the PACS workstation to complement the images from the examination under consideration (H. K. Huang, 2004).

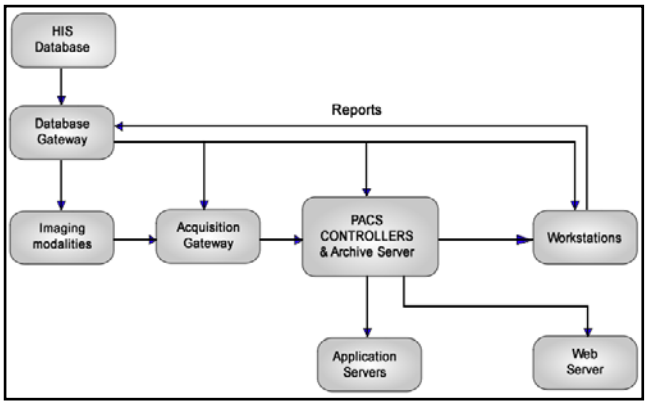

FIG. 1 PACS BASIC COMPONENTS AND DATA FLOW
(H. K. Huang, 2004)

The PACS infrastructure consists of a basic skeleton of hardware components as imaging modalities, data/modality interfaces, patient data servers, storage devices, host computers, communication networks, and displaying systems. These components are

integrated by a standardized and flexible software system for communication, database management, storage management, job scheduling, interprocessor communication, error handling, and network monitoring. The software modules of the infrastructure should ensure the image receiving, routing, retrieving, archiving, grouping, RIS/HIS interfacing, and PACS database update (H. K. Huang, 2004). PACS network components and its data flow is shown in figure 1.

Motivations

The main goal of the project is to build digitalized, easy to use, and portable interaction system that automates the request, deliver, view, report, store, and retrieve the diagnostic images allowing the technologists to deliver the images and the radiologists to read these images and perform the diagnosis. Also it helps the clinicians to timely, efficient and online access to the patients' data.

These main motivations behind the thinking to develop this system are:

1. Providing each patient with Electronic Health Record (EHR) which includes patient's demographic data and medical data instead of using traditional paper-based records.
2. Creating "medical exams folder" to each patient which includes patient's images and reports. This folder can be accessed electronically.
3. Online access to the patient's data (EHR, exams, and reports) at anytime from anywhere.
4. Providing electronic delivery of the acquired exams once they are acquired. This reduces the access time to these exams and eliminates exams loss.
5. Direct access to the patient's exams (current and prior) helps the radiologist to access the exams directly and send the diagnostic report.
6. Allowing online reporting through implementation of online text conference system which provides direct discussion and reporting between the referring physician and the reading radiologist.
7. Implementing teleradiology service which allows transmitting of patient's images to external radiologist or consultant for the purposes of interpretation and/or consultation. This allows the radiologist to provide services without actually having to be at the location of the patient.
8. Implementing simple telemedicine system that helps the doctors to gathering all necessary patient information, examination results, and diagnostic reports. The consultant will read the request and can send his findings directly.
9. Providing direct messaging system among the system members. This increases the communication and interaction among the members.
10. Providing online requested exams. Also scheduling these exams on each modality by providing each request with sequential number "exam accession number". This organizes the crowding on each modality and provides the technologist with all the required information.
11. Direct delivery of diagnosis reports to the referring doctor. This causes to reduce required time of the reports delivery (report turnaround time).
12. Providing each patient a daily electronic medication sheet which contains complete description about his/her medicines and their doses.
13. Allowing each administrator to manage his/her patients directly through providing direct access to their data and manage it.

Pacs Management System

PACS management system is standardized, flexible software system for communication, database management, storage management, job scheduling, interprocessor communication, error handling, and network monitoring. The software modules should ensure the image receiving, routing, retrieving, archiving, grouping, RIS/HIS interfacing, and PACS database update. It should provide data integrity, security, and authenticity. Also it is versatile and provides education and researching enhancements. The modules permit the PACS network components to work together as a system rather than as individual networked computers (H. K. Huang, 2004).

The PACS image management software runs on the servers to provide storage and communication services to the modalities and the review workstations (Guy Paré, David Aubry, Luigi Lepanto, and Claude Sicotte, 2005).

System Design Phase

In this stage of system development the technical solutions in terms of software, interfaces, databases, and hardware are determined.

Software Design

In addition to ensuring images receiving, routing, retrieving, archiving, grouping, data security and reliability, RIS/HIS interfacing, and PACS database update, PACS software should provide PACS data to external PACS like teleradiology, teleconsultation, and conference rooms. These functions make the system is complicated-structure system so that the proposal is using system decomposition technique to decomposing the PACS network management system into numbers of subsystems that incorporate to perform the essential functions of the PACS software. However PACS network management system is decomposed into seven subsystems which include the required subsystems for providing HIS/RIS interfacing. The subsystems communicate directly through database-to-database transfer. However these subsystems are:

1. Enterprise Portal Subsystem: This subsystem provides access point to other subsystems and contains education and researching enhancements like radiology teaching system.
2. Patients ADT Subsystem: It is used by departments' administrators (specialists) to provide PACS with HIS interfacing. It provides the specialists with all tools that are associated with patients register, admission, discharge, transfer, and exam requesting.
3. PACS Broker Subsystem: It is responsible for managing system's internal operations. It provides the required tools to manage patients' folders, directing exams requests and admitting patients in the PACS
4. Exams Displaying Subsystem: It provides radiologists with all the required tools that enable to view exams worklist, read images, access patients archived exams, and dictate diagnostic reports.
5. Clinical Doctors Subsystem: It enables the clinical doctor to access and view the data of his/her department patients.
6. PACS Administration Subsystem: It concerns with all aspects of system administration functions like members management, system configuration, and data management.

These subsystems are secured through using user identification and authentication technique that requires a using login ID/password to access the intended system. The passwords are stored in databases as encrypted ones using md5 encryption method. The workflow of the suggested system is shown in figure 2, where each member can access to one of the PACS subsystems according to his/her account data. The complete system appears as single system as integrated subsystems through allowing members to access their systems through the same access point, enterprise portal subsystem. The dataflow among the subsystems is shown by colored arrows where the flow starts in patient registration by specialist and then send examination request and so on.

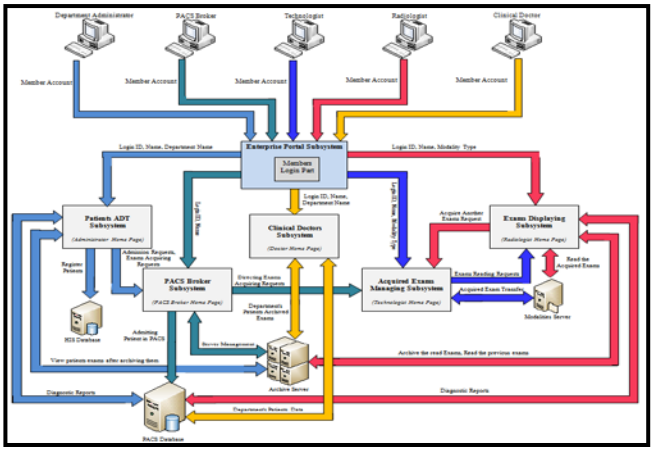

FIG. 2 PROPOSED SYSTEM WORKFLOW

The software design based on Structured Systems Analysis and Design (SSAD) method which is a waterfall method by which an information system design is produced (Donald Yeates and Tony Wakefield, 2004).

Modular architecture technique was used to build independent modules for the subsystems. Each module (or group of modules) is designed to perform specific task, for example login module checks the validity of the login data while exam compression requires more than one module to be performed.

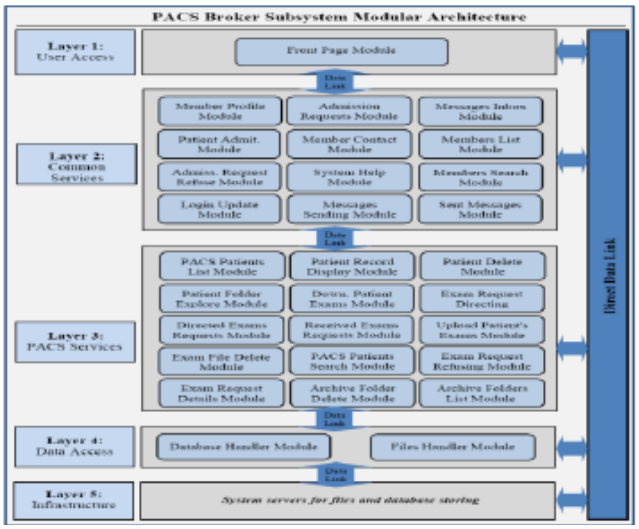

FIG. 3 PACS BROKER SUBSYSTEM MODULAR ARCHITECTURE

The n-tiers design architecture model (Cristian Darie,

2008) is used to represent the architecture of each one of these subsystems. The architecture of each subsystem consists of number of tiers and each tier is divided into number of components. Each component has number of modules. This model leads to make the architecture more flexible where new modules can be added to the layer without the need of big change of the system. Figure 3 shows the modular architecture of PACS broker subsystem as an example of the architecture for the other subsystems.

Database Design

MySQL is used as relational database for storing system data. Number of databases is used instead of one database. In order to make more restriction on databases the archive system database is used for storing archive related data, while reports database is used for storing the diagnostic reports. The data of patients/images are stored in many tables in order to provide high normalization. Database server login data are stored in isolated module as encrypted data.

The Main Supported Techniques

The main techniques that had been used to build the main parts of the system are open source platforms, code reuse technique, and the reverse code generation. Open source platform is used due to the great potentials and the huge development committee that is available online like Apache Web Server, MySQL Database Server, Filezilla FTP server, and PHP Programming Language, while the code reuse technique is the most powerful tool that the programmer had used it to create new application.

Reverse code generation technique is used to build open modules to be like the commercial ones by using the "See and Make" principle. This technique done by seeing the other closed-source projects and find out what is the service that they gave, then trying to make a copy module that give the same service and then develop it. This technique was used because many PACSs software are commercial and intra-hospital operated.

Development Environment

The proposed network for operating and testing this project is shown in figure 4. This figure shows the project development environment, where there are two networks: one network is used to connect clients' workstations together through network switch #1 (Catalyst 2950 Fast Ethernet switch) and connected with the second network that is used to connect the servers that are required to store PACS data together through another network switch #2 (Catalyst 2950 Fast Ethernet switch). The two networks are communicated through one router (Cisco Router 2800). These details are mentioned to give an idea of system implementation, that are achieved in an webserver applications lab. The hardware specifications for servers are shown in table 1. Modality simulator is generic PC used to simulate the medical modality and has some medical images. Still the required servers are:

1. Apache Web Server: This server used for hosting PACS management system. It has PHP as server-side scripting.
2. MySQL Database Server: This server is used to store PACS databases and images location.
3. Modalities Server: It is FileZilla FTP server used as short-term archive system to store the acquired exams from the modalities temporarily.
4. Archive System Simulator: This server is also FileZilla FTP server used to simulate the long-term archive system to store the read exams permanently.

System Security

Many options are used to enhance the security and integrity of data in PACS. These options include:

1. Using user identification and authentication technique that restrict the access to PACS data on the authorized members only.

TABLE I HARDWARE SPECIFICATION FOR NETWORK SERVERS

Server Type	Operating system	Server Software	CPU	Memory	Network Interface	IP Address
Web Server	Windows XP Professional	Apache HTTP Web Server (2.2.16) with PHP (5.2.8)	Intel Core2 Quad 2.66 GHz	4 GB	Intel 82567LM-3 Gigabit Network Connection	192.168.4.1
Database Server	Windows XP Professional	MySQL DB Server (5.1.32)	Intel Core2 Quad 2.66 GHz	4 GB	Intel 82567LM-3 Gigabit Network Connection	192.168.4.2
Modalities Server	Windows XP Professional	FileZilla FTP Server (0.9.37)	Intel Atom 1.6 GHz	2 GB	Intel 82567LM-3 Gigabit Network Connection	192.168.4.3
Archive Server	Windows XP Professional	FileZilla FTP Server (0.9.37)	Intel Atom 1.6 GHz	2 GB	Intel 82567LM-3 Gigabit Network Connection	192.168.4.4

2. Using SSL module with apache server to secure the channel ween betthe Web server and clients browsers.
3. Using one page as default page for any anonymous user when he/she tries to access any module without having the privilege to access it.
4. Encrypting passwords in databases using Md5.
5. Using FTP server software in archiving system protects the access to the exams files where the IPs external PACS network is prevented from accessing the server.
6. Obligation the member to select his member-ship type before trying to access intended subsystem makes the system more secure against hackers and automatic passwords recovery programs.

Images Viewer

Image viewer is used where the actual diagnosis takes place. Doctors are provided with a variety of tools to measure distances, angles, perimeters and areas of suspicious masses found in the images. These measures are typically known in the PACS terminology as "annotations" (Seok-Hwan Jang, 2004). Additionally, image transforms (Jacob Beutel, 2000) to adjust contrast, brightness, zoom and rotation are also provided. The used DICOM viewer was built using Java programming techniques. Figure 6 depicts DICOM images viewer.

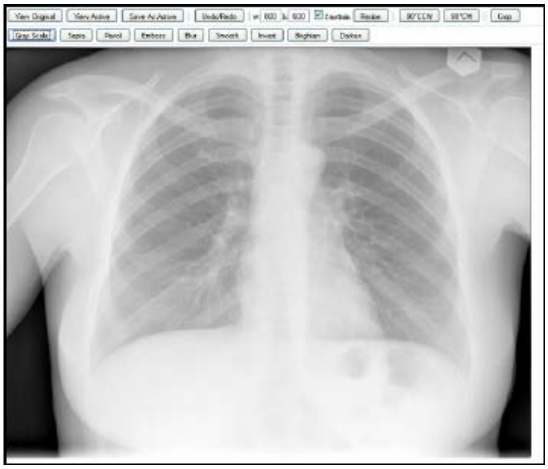

FIG. 6 IMAGES VIEWER MODULE SCREENSHOT

System Main Modules

The core of each subsystem is compounded from many modules that are implemented to perform the functions and services associated with the subsystem. All this modules in the sequential layers are linked by "Data Link" that is responsible for integration of all available modules together. While the modules of all the layers are communicated through "Direct Data Link". However the list of the main modules of all the subsystems:

- "PACS Main Interface Module": this module contains system news part, member login part, and the links for all the services provided within the system as shown in figure 7.
- "Front Page Module": this module is found with all the subsystems to show the main interface of the subsystem and the links for all the offered tools and services.
- "Patient Registration Module": (Patients ADT system) this module helps specialists to register new patient in the HIS as shown in figure 8.
- "Patients List Module":(Patients ADT system) it shows the list of patients to the specialists with many options to view and manage patient data/images. It is shown in figure 9.
- "Exam Requesting Module": (Patients ADT system) it is used for creating and sending new examination request to RIS through PACS broker.

FIG. 7 SYSTEM MAIN INTERFACE

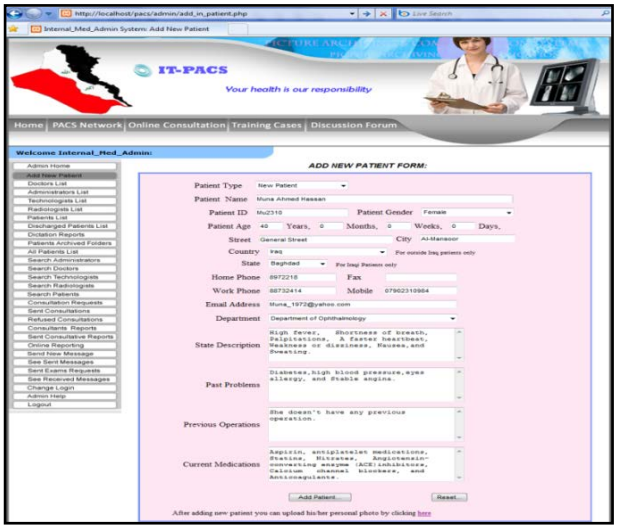

FIG.8 THE NEW PATIENT FORM REGISTERATION

FIG. 9 PATIENT LIST MANAGEMENT

FIG. 10 DIGITAL X-RAY MODALITY WORKLIST

- "Patient Exams Module": (Patients ADT system and Clinical Doctors system) it shows list of archived exams of the patient with many options to view exam's associated report, view the exam, and send it remotely (teleradiology).
- "Report View Module": (Patients ADT system) it displays the details of the diagnostic report.
- "Admission Requests Module": (PACS Broker system) it used to display the received admission requests.
- "Previous Exams Uploading Module": (PACS Broker system) it is transferred prior exams from permanent storage units to patient's folder on the archive.
- "Received Requests Module": (Acquired Exams Managing system) this module displays the directed exams requests that should be acquired.
- "Archive System Management Module": (PACS Broker Subsystem) this module is used to manage patient's folders on the archive system.
- "Acquired Exam Delivering Module": (Acquired Exams Managing system) this module used to transfer the acquired exam from modality gateway to the modality directory on the modalities server. It fetches patient's EHR and stores with exam package and compresses the exam using ZIP method package before transferring it.
- "Modality Worklist Module": (Exams Displaying system) lists the current unread exams in the modality directory on the short-term archive (modalities server). Its screenshot is shown in figure 10.
- "Archived Exams Fetching Module": (Exams Displaying system) this module fetches archived exam(s) to the reading radiologist or referring doctor.
- "Reporting Module": (Exams Displaying system) this module used to view the form of the report that the radiologist should fill it when read the exam.

Conclusions

The system had been tested in the lab of Information Engineering College of Al-Nahrain University, where the conclusions that were inferred from this experience are:

1. Decomposing PACS network management system into number of independent subsystems helps to:
   - Easily develop the systems where the new features can be implemented and integrated directly.
   - Disallow sets of members to access the system at certain times.
   - Improve scalability and availability.
   - Improve error tolerance.
   - Improve expendability via the ability to integrate the system with hospital information systems.
2. Compressing the exam before storing them in PACS servers helps to reduce exam's occupied size on the servers and the required transmission rate.
3. FTP commands helps to manage the directories on the files servers and the stored exams directly using PHP.
4. Star network topology with high-speed

Ethernet technology allows to easily isolating the fault and ensures very high-speed performance (100 Mbits/s data rate).

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