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EIR: Enterprise Imaging Repository, An Alternative Imaging Archiving and Communication System

Jiang Bian, Umit Topaloglu and Cheryl Lane
Information Technology
University of Arkansas for Medical Sciences
4301 W. Markham St.
Little Rock, AR 72211, USA
{JBian, UTopaloglu, LaneCherylF}@uams.edu

Abstract— **The enormous number of studies performed at the Nuclear Medicine Department of University of Arkansas for Medical Sciences (UAMS) generates a huge amount PET/CT images daily. A DICOM workstation had been used as "mini-PACS" to route all studies, which is historically proven to be slow due to various reasons. However, replacing the workstation with a commercial PACS server is not only cost inefficient; and more often, the PACS vendors are reluctant to take responsibility for the final integration of these components. Therefore, in this paper, we propose an alternative imaging archiving and communication system called Enterprise Imaging Repository (EIR). EIR consists of two distinguished components: an image processing daemon and a user friendly web interface. EIR not only reduces the overall waiting time of transferring a study from the modalities to radiologists' workstations, but also provides a more preferable presentation.**

I. INTRODUCTION

The rapid development of medical imaging technologies raise the concern of handling, storing, retrieving and transmitting the images and attached patient information in healthcare. Although, the Digital Imaging and Communications in Medicine (DICOM) standard enables the integration of modalities, servers, workstations and printers into a picture archiving and communication system (PACS), the performance of such systems are often not efficient for patient cares. The transmission from the modality to the physician's reading workstation often takes longer than desired. Some believes that the problem resides on the DICOM protocol itself, which is often being considered inherently slow or chatty. Although, DICOM itself is a non-proprietary standard that specifies the digital imaging format, file structure and data interchange protocols for transferring biomedical images and clinical data, it does not enforce the implementation. Often, the slowness and poor performance are caused by poor implementation from the vendors or more often because of a problematic network deployment. Nonetheless, DICOM is unequivocally the only standard for modality and PACS communications. However, a PACS system often cost the institution a fortune to be deployed and cannot be shared between departments in a big organization without costly efforts. It results in a situation where several PACSs from different vendors co-exist in the same research community, which is not only wasteful cost-wise, but also makes it hard to share information between researchers. Furthermore, an institution often chose to use a DICOM workstation as a "mini-PACS" to replace a real PACS server and save the cost, which certainly has neither the computational power nor the network capability to serve a large community.

Therefore, in this paper, we describes a low-cost Enterprise Imaging Repository (EIR) system, that processes, hosts, archives and presents the medical images centrally. EIR also provides a uniformed web interface using Web 2.0 technologies to help the physicians view the images through the Internet from a regular browser. EIR can be integrated with hospital's ADT (admission, discharge and transfer), so that the patient information, such as patient demographics, diagnosis and reports, etc., are well-organized, more important, thoroughly validated and verified. Furthermore, EIR provides various communication channels to fetch/receive the images from the modalities or another PACS server. EIR implements the standard DICOM network communication protocol, therefore, it accepts DICOM push from any modalities. But also, images can be exported from the modalities to a dedicated network share drive as flat DICOM files, and then the images will be properly processed (i.e. error check, patient information check, etc.) by a daemon application. The advantage of exporting images to a shared network drive is the performance. Although, theoretically, DICOM can approach the speed of raw sockets just as ftp or http can, more often the problem is that the DICOM communication protocol is not properly implemented by various modality manufacturers. Moreover, the cost of deploying an EIR system is much lower than the cost of an PACS server from a vendor. Last but not least, EIR's web interface supports uploading images (i.e. pathological image, etc.) from the browser and EIR provides an immediate view of these images through the web. EIR supports a vast number of image types other than the standard DICOM, such as JPEG, TIFF, PNG, etc.

The rest of the paper is organized into three sections. Section II gives a brief overview of related background studies, such as DICOM protocols and its various open-source implementations. In Section III, we present the overall design of the EIR system, especially the organization of the web interface and its implementation of DICOM protocols through dcm4che [1]. We will conclude the paper with emphasis on the importance of developing a EIR like system,

where not only images are properly stored and handled, but also the share of medical information can be easily achieved with proper security in place. Furthermore, as future works, EIR can be expanded not only storage capacity-wise, but also its performance can be improved by employing cloud computing and load balancing technologies. Moreover, it will be a great benefit to support HL7 in EIR to automate some of its tasks such as generating work list, patient registration, etc. Using HL7 to improve the integration of EIR with other Hospital Information System (HIS) and Radiology Information System (RIS) will certainly be a plus in a hospital environment.

II. Related Work

A. The DICOM Standard

As DICOM [2] is undoubtedly known as the most popular standard for medical image storage and communication. DICOM standard was started by the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) jointly in 1983. It promotes the communication of medial images and related clinical information independent to various device manufacturers. Also, the DICOM standard helps the development and expansion of PACS that helps the distribution and viewing of medical images. Part 10 of the standard describes a file format for storing and distributing images. Unlike most other Electronic Medical Record (EMR) standards, DICOM images use a binary encoding with hierarchical data sets. A DICOM file is constituted of a DICOM header and the image itself. The DICOM header stores patient/study information and some other meta-data such as study instance id, image dimensions, etc.).

DICOM standard describes a set of services to help transmission of images/data over a network in addition to the file format. A list of DICOM services includes:

- Store service is used to send image/data objects to a PACS or workstation.
- Query/Retrieve provides a workstation a way to find and retrieve certain image objects.
- Modality Worklist and Modality Performed Procedure Step give modalities the ability to obtain a list of scheduled examinations as well as the patient information.
- Printing service is used to send DICOM images to a DICOM capable printer. DICOM standard also helps to ensure consistency between various display devices.
- DICOM Files is a file format standard to help store medical images and related clinical data on removable storage devices.

EIR uses an open-source DICOM toolkit, dcm4che, to properly handle the DICOM files coming out of the modality.

B. DCM4CHE DICOM Toolkit and DCM4CHEE DICOM Clinical Data Manager System

Gunter Zeilinger wrote the popular JDicom utility suite using Java DICOM Toolkit (JDT) in 2000. And it evolved and expanded into the current DCM4CHE DICOM toolkit and DCM4CHEE DICOM Archive system. DCM4CHE is a high performance and open source implementation of the DICOM standard. It includes a set of libraries to manipulate DICOM objects or facilitate the communications among DICOM-enabled devices and systems. DCM4CHE developed using platform independent Java technologies and is envisioned to be used on various devices running different operating systems.

DCM4CHEE is built on the success of DCM4CHE that is intended to provide a open-source set of applications to provide a number of clinical services. Mostly, DCM4CHEE is considered to be used as a DICOM image manager or a PACS, to provide services for a DICOM viewer such as OsiriX [3], K-PACS [4], ClearCanvas [5], etc. It provides a set of modules to facilitate the radiologist as well as the system administrators, which includes:

- a robust Web-base User Interface to ease administrative tasks.
- DICOM interfaces to provide image archiving services for modalities,
- HL7 interfaces, so that it can be easily integrated into existing HISs and RISs,
- Web Access to DICOM Objects (WADO) and IHE Retrieve Information for Display (RID) interfaces to enable access the images from the Web,
- an Audit Record Repository (ARR) for security purpose,
- Media Creation (CDW) service to export images onto a removable storage device,
- both XDS/XDS-I as a Document Repository and an Imaging Document Source,
- Xero component that provides a thin-client for clinical access to patients and studies.

C. Web 2.0 Technologies

EIR is a web-based information management system with a few standalone applications that facilitate the image processing. EIR website is mainly written in PHP [6], a Hypertext Preprocessor, mainly designed for building dynamic web pages. EIR adopts a lot Web 2.0 technologies, such as ajax, javascript frameworks, web services, etc, and design concepts, which provides a better user interface, and a more user friendly information management platform.

III. Implementation

A. Problem Statement

EIR was first developed to solve the performance issues in an existing PACS architecture at University of Arkansas for Medical Sciences (UAMS) Nuclear Medicine department. There are two SIEMENS PET/CT modalities with full work load, which is around 10 patients/studies each day. Each study generates three sets of images: a set of Computed Tomography (CT), a set of raw Positron Emission Tomography (PET) and a set of corrected PET, which results around average 500 image slices each, and total 350 MB storage space for each study. A workstation is used to act as a ”mini-PACS”, to which all the images are pushed from the modalities. Then the studies/images were being routed manually by the technicians to the doctor’s reading

workstation or exported into a CDW and delivered to the radiologists. Normally, it takes three to four hours for a technician to prepare a study after scanning the patient, and it's very labor intensive.

B. Overview of Nuclear Medicine EIR

The bottle-neck here is obvious the "mini-PACS" workstation that is responsible to receive and route a huge amount of image data. However, it is cost inefficient to deploy a fully configured PACS server. Therefore, we proposed the Enterprise Imaging Repository solution that improves the performance dramatically and reduce the average processing time per study from 4 hours to less than 20 minutes. The following figure, Figure 1, shows the overall architecture and work flow of the EIR system.

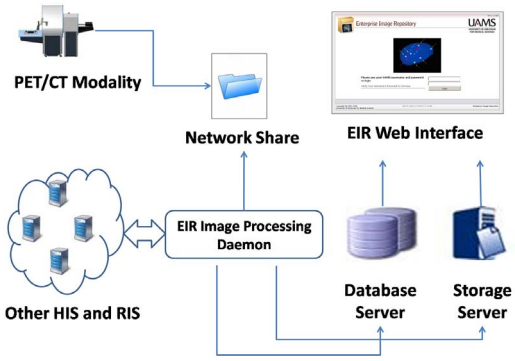

Fig. 1. Overall Architecture of Enterprise Imaging Repository

After scanning a patient at the modality, the technician pushes all images related to this study to a specific location on the network. The shared folder is password protected for security purposes. The EIR Image Processing Daemon (EIR-IPD) periodically scans the shared folder and processes all income DICOM images accordingly. EIR-IPD implements a DICOM parser to fetch the patient and study related information from the DICOM images. Moreover, EIR-IPD links to other hospital information systems either through direct database queries or web service interfaces. The patient information will be verified against the patient database, and the study accession number is checked against the modality's work list from the examination scheduling system. A new project will be created in the EIR database, or the study images will be linked to an existing project. The incoming DICOM images are first packaged with a compression algorithm and stored on a RAID-enabled hard drive. Moreover, the image data is not only protected by the RAID technology, but a uncompressed backup copy is also sent to a secondary network storage device. Currently, there are two ways for the physicians to access the studies in EIR for various reasons. They can browse and find a particular study through EIR's web interface and download the entire study from the web page. Or, they can directly access the secondary network storage device.

C. EIR Image Processing Daemon

As aforementioned, EIR-IPD is running as a daemon thread on the server and monitoring the network share for income DICOM files. First of all, the network share is password protected for security purpose. EIR-IPD implements the DICOM standard by utilizing DCM4CHE DICOM toolkit to read the DICOM header for study meta-data, such as StudyInstanceID, StudyDate, StudyTime, AccessionNumber, PatientID, etc. The patient information will be checked against the hospital's patient registration system, and a flag will be raised if there is a miss match. There are a number of procedures in EIR-PID's file validation routine. For example, the integrity of the study will be checked by comparing the number of images received with NumberOfSlices recored in the DICOM header.

If there is no error found during image validation stage, EIR-IPD packs all images of the study into a compressed zip file. The compression operation in EIR-IPD is implemented using TrueZIP [7], a pure Java library with good performance and high compression rates. Normally a study contains around 1,500 image slices, and around 400MB. After compression, the size of a study package is reduced to under 200MB, which indicates an average 50% compression rate. The compressed study package will be stored on the EIR web server, and a copy of the original uncompressed study is sent to a secondary network storage device to be stored permanently. The backup copy is not compressed, so that the radiologists can access the studies directly by simply mapping the network storage device as a network drive on their workstations. However, for security control purpose, the secondary access method is limited to people within UAMS intranet protected by the firewall. The studies on the secondary drive is organized by patient and then by study date for easy searching and accessing.

Upon study's images properly processed and handled, EIR-IPD will create or update the EIR database to record the basic patient information and necessary study information for future displaying on the EIR's web interface.

D. EIR Web Interface

EIR is envisioned to be deployed as an universal web-based image management system. Although EIR was originally designed for the Nuclear Medicine department at UAMS as a PACS replacement, we intended to make its architecture and components more flexible, so that EIR can be deployed as a centralized image archiving and management system with universal user interface across the UAMS campus. Therefore, EIR web is designed under template-based concept. EIR is broken into several small systems based on department boundary. Each subsystem may implement different study templates to suite individuals' needs to capture different clinical data. For example, a thyroid center EIR site might need to display ultrasound movies in addition to static DICOM images. Therefore, we implement a set of commonly used field components, such as Medical Record Number (MRN), text field, text blob, date field, static image section, etc. A project template can

be easily and quickly constructed by adding and organizing standard field components. Moreover, customized field can also be rapidly developed and easily plug into a project template to meet the various requirements. The construction and manipulation of a system's project template can be easily performed through database operations dynamically. A number of Web 2.0 technologies, such as Asynchronous JavaScript and XML (AJAX), Simple Object Access Protocol (SOAP) web services, etc., have been used in EIR web to provide a friendly and easy to use graphic user interface. Figure 2, shows the detail view of a sample project from the EIR Web.

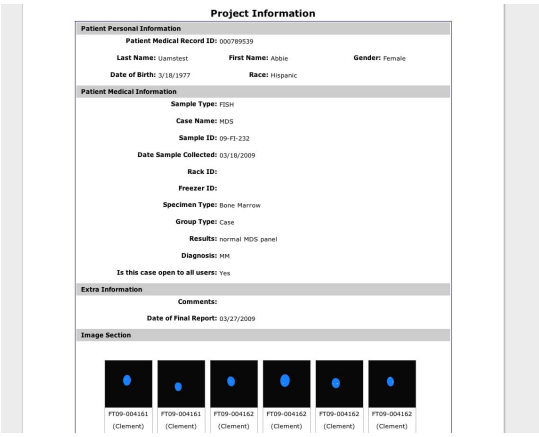

Fig. 2. Project Information Page of EIR Web

E. Security, Access Control and Auditing Service

Security is for certain the most important concern while developing a system in medical environments. EIR is designed with a fully understanding of patient privacy and protection of medical data. As aforementioned, the network shared folder in EIR resides behind the institution's firewall. Furthermore, it is password protected. In terms of EIR Web, it seamlessly integrated with organization's Active Directory service through Lightweight Directory Access Protocol (LDAP) for user authentication and a built in Role-based Access Control (RBAC) to restrict system access to authorized users. Within an organization, roles are created for various job functions. The permissions to perform certain operations are assigned to specific roles. Radiologists, technicians or other physicians are assigned particular roles, and through those roles acquire the permissions to access particular system functions. For example, a system admin can see all studies of any EIR subsystem, while a physician can only see certain studies/patients within his/her department.

EIR Web also implements an auditing service to provide security logging. Each operation in EIR triggers an logging event, which records who, when and which protected element has been created, accessed, updated or deleted. Therefore, a security breach can be quickly detected or even prevented.

IV. Conclusions

In this paper, we describes a robust, high performance and modularized web-based image management system. Also, we demonstrates a success implementation of EIR that is used to replace a traditional PACS for not only better performance but also more preferable presentation. EIR consists of two distinguished components: an image processing daemon and a user friendly web interface. The DICOM images are validated and the patient information in the images are verified. EIR are seamlessly integrated with other hospital information systems or radiology information systems for a better work flow. Furthermore, EIR Web adopts a template-based design concept to promote modularity, so that a new subsystem can be easily constructed under minutes. Considering that EIR is intended to be used in a medical environment, the security mechanism is highly critical. The direct access to the network share in EIR within the organization firewall is protected by password. EIR Web implements a reliable RBAC mechanism to prevent unauthorized access to protected elements. Moreover, EIR Web's built in security auditing service ensures the detection of a security hole or even can be used to prevent a security breach.

V. Future Works

Although, EIR has been shown as a reliable and better performed medical image management system comparing to a traditional PACS, the performance can be further enhanced by deploying EIR into a grid environment with server load balancing to get optimal resource utilization and maximize the throughput.

Current implementation of EIR communicates with other HISs and RISs through either direct database access or web service interfaces. HL7 has been proved to be the most popular standard for the exchange, integration and sharing electronic health information. It will be a great benefit to add HL7 support into EIR for a more standard communication mechanism.

Last but not least, currently, EIR receives the DICOM images as flat files from the modalities, however, not all vendor's DICOM viewer workstation supports opening images directly from the hard drive. Adding additional DICOM services such as sending images through DICOM network protocol will be very beneficial.

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