Journal of Digital Imaging

# Developing a Medical Image Content Repository for E-Learning

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**The integration of medical informatics and e-learning systems could provide many advanced applications including training, knowledge management, telemedicine, etc. Currently, both the domains of e-learning and medical image have sophisticated specications and standards. It is a great challenge to bring about integration. In this paper, we describe the development of a Web interface for searching and viewing medical images that are stored in standard medical image servers. With the creation of a Web solution, we have reduced the overheads of integration. We have packaged Digital Imaging and Communications in Medicine (DICOM) network services as a component that can be used via a Web server. The Web server constitutes a content repository for searching, editing, and storing Web-based medical image content. This is a simple method by which the use of Picture Archiving and Communication System (PACS) can be extended. We show that the content repository can easily interact and integrate with a learning system. With the integration, the user can easily generate and assign medical image content for e-learning. A Web solution might be the simplest way for system integration. The demonstration in this paper should be useful as a method of expanding the usage of medical information. The construction of a Web-based repository and integrated with a learning system may be also applicable to other domains.**

**KEY WORDS: Content repository, DICOM, WADO, E-learning**

## INTRODUCTION

In a modern healthcare environment, medical image acquisition modalities, image processing systems, and viewing and reporting systems are integrated by Digital Imaging and Communications in Medicine (DICOM) protocols. All medical images in the integrated environment are stored in an image server (image managing and archiving system). The image server supports DICOM query/retrieval protocols so that different image viewing systems can use the protocols to search and acquire images stored in the server. The modalities, image processing systems, and storage systems integrated via the DICOM protocols constitute the core of a Picture Archiving and Communication System (PACS), which is the foundation of clinical image diagnosis. The DICOM server is a repository that stores medical images but does not usually handle other digital clinical data formats. The DICOM standard is so successful that it would be useful to expand its usage as a standard to other clinical application domains. For example, in the Integration Healthcare Enterprise technical framework, a profile called "Access to Radiology Information"[1] was defined to provide access to clinical information in the DICOM data formats and protocols. The profile is useful both to the ra-

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*Online publication 24 May 2006*
*doi: 10.1007/s10278-006-0588-6*

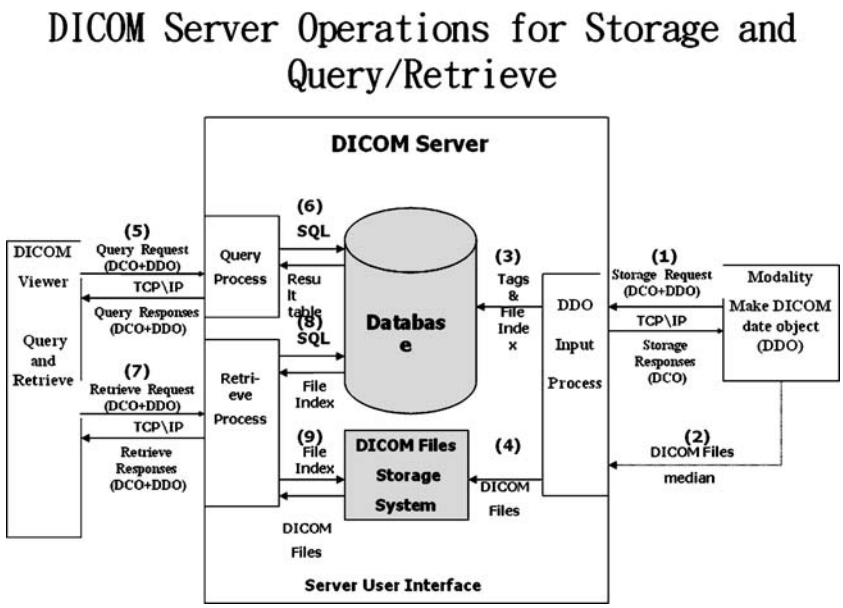


**Fig 1. A schematic diagram that shows the main protocols and interactions of modality, DICOM image server, and viewer.**

diology department and to other departments such as pathology, surgery, and oncology. Nonradiology information, such as pathology reports and laboratory examination results, may also be accessed using DICOM protocols and formats. Recently, the Image Management System (IMS) Global Learning Consortium has defined a specification for digital repository interoperability for e-learning. Some core functions (Submit, Search, Expose, etc.) for interoperability between systems [content repository, Learning Management System (LMS), Learning Content Management System (LCMS)] were defined in the specifications.[2] The requirements and functionalities of the IMS-defined digital repositories are similar to the protocols of DICOM server defined in the DICOM standard. IMS has recently defined those core functions. However, the detailed specifications and the interaction protocols are still not defined. More investigation is required to develop digital repositories. On the other hand, the image server in PACS is a well-adapted and commercialized product.[3–5] Many concepts and specifications used in PACS might be adapted to the e-learning system.

The DICOM standard was defined for its domain-specific purpose. It has specific coding mechanisms and communication protocols. This constitutes a barrier for information technicians who are not familiar with the DICOM standard when implementing medical image applications. It may also restrict the development of medical image applications that are outside of the scope of DICOM standard, such as e-learning for medical education. This paper focuses on adapting the e-learning requirements and specifications and expanding the functionalities and usage of the PACS server. We have constructed an interface system that can integrate with PACS. The system also provides Web accessibility so that we can use the browser to search and view medical image stored in PACS. Combined with PACS, the gateway system constitutes a Web-based medical image content repository. We will investigate the interactivity and integration protocols between LMS and the repository. By means of the integration, the user can easily generate Web-based medical image content and assign the content as courseware in LMS. The system is a useful tool for doctors who prepare clinical images for case studies on the Web.

## METHODS

### Basic Functionalities of PACS Server

There are three main system components in PACS: modalities, the DICOM server, and the image viewer. Medical images are generated by modalities, stored in the server, and

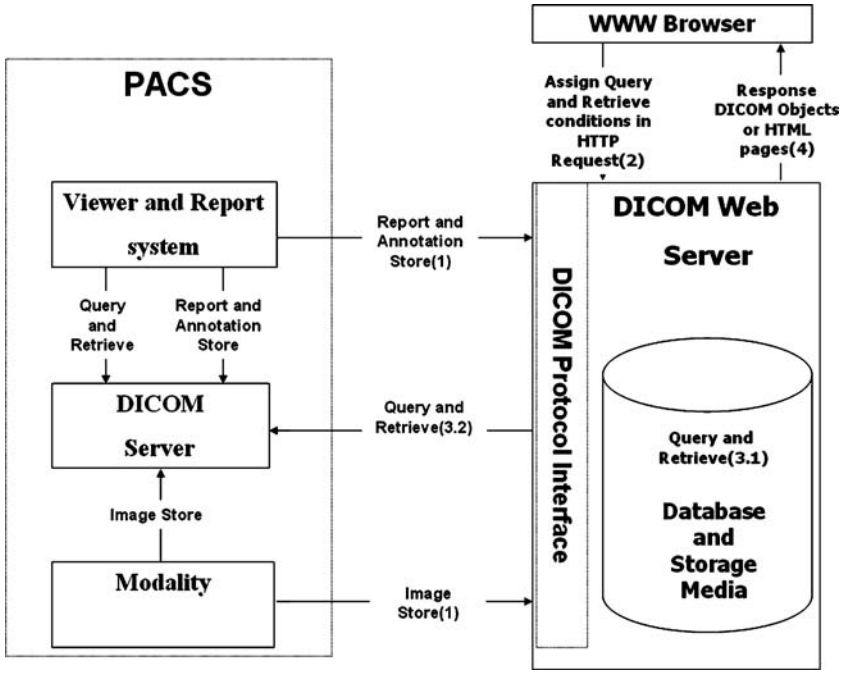


**Fig 2. The architecture and interactions of the PACS, image content server, and browser.**

queried and retrieved by radiologists via the image viewing systems who subsequently perform their diagnosis using the same image viewing system. The functions and interactions of these systems are shown in Figure 1.

There are three main protocols for integration in PACS (Image Store, Query, and Retrieve). The modality stores medial images on the server by means of a storage protocol. The image viewer searches images that have been stored on the server through the DICOM query protocol. These images are taken from the server back to viewer by the DICOM retrieve protocol. All of these protocols are defined in DICOM standard part 4.[6] DICOM defines the data formats and protocols for integration. Implementation and the database schema inside the systems are out of the scope of DICOM standard. However, for the purpose of supporting the powerful query and retrieve protocols, most DICOM servers have similar functionalities and database schema inside the system.

## Web-Based Image Content Repository

As described in Introduction, DICOM has complicated coding mechanisms and communication protocols. This may restrict the progress of medical image applications outside the scope of the DICOM standard. The DICOM standard committees are also aware of this barrier upon expansion of medical images to other uses. A Web-based access extension has been defined in the DICOM standard recently to expand the usage of medical image.[7] There are two approaches to expand PACS functionality for Web access. One is to implement the Web interface on the DICOM server directly. This approach will constitute an image server that supports traditional DICOM query/retrieve protocols as well as Web accessibility. Both the DICOM viewer and the Web browser will be able to link to the server to acquire and view medical images. This is a proper approach for developing the DICOM server and Web server simultaneously, and it will produce a single product for handling medical image. However, lots of PACS servers are commercial products that have already been set up in a healthcare environment. It would be very difficult, if not impossible, to modify these commercial systems. For those DICOM servers that already have been set up in healthcare departments, another approach to the building of Web accessibility might be much more suitable. This approach constructs a gateway system that supports DICOM query/retrieve protocols as a role of Service Class User and also builds a Web server in the gateway system. Consequently, the gateway system would be able to search and acquire images stored on the PACS server, and we could access medical images through a browser. In this project, the medical image content repository acts as both a gateway and a server. Both approaches described above can be developed for the content repository. The architecture and functionalities of the server are described in Figure 2.

As the architecture above demonstrates, the system is implemented through the standard DICOM network communication services: Storage, Query, and Retrieve in the content server. The Web interface that provides functions for searching and displaying medical images on Web pages is also constructed on the server. The DICOM protocols implemented in the content server constitute an interface so that the server can communicate with PACS system freely. DICOM images generated by modalities or reports generated in a report system

may be stored in the content server using DICOM storage protocols—procedure (1). The WWW browser uses http request to assign query conditions and identify images that are to be displayed on a browser—procedure (2). The content server searches DICOM objects and finds those that meet the query conditions in http request. The searching procedures include exploring the DICOM images stored in the content server—procedure (3.1)—or exploring images archived in the PACS server. To search images that were generated and stored in a standard PACS, the content server translates the conditions in the http request into DICOM query/retrieve objects and uses the query/retrieve protocols to search the images in the PACS server—procedure (3.2). Eventually, the content server responds by passing the search results to the browser—procedure 4. The results might be pure HTML Web page or content from the server that correspond to the DICOM objects, provided that a DICOM viewer has been plugged into the Web browser.

## Medical Image Repository Web Page Requirements

To employ a Web-based server as an image repository for e-learning, there exist some other requirements and considerations; image repository must have the ability to integrate and interact with the LMS. By means of the interactions, learning objects are generated and assigned into the LMS by the courseware creator. Several essential Web pages are needed to be implemented on the content server for this archiving. The Web pages and functionality requirements of the image repository are described in the following sections.

### *Repository Search Portal and Search Result*

Typically, courseware creators search and explore the content repository. After that, the creators would assign specific learning content to the LMS for learners. The search portal page is the image repository entry point. This portal should have the ability to authenticate users. After authentication, the repository portal will provide interface for creator to input criteria for searching and exploring medical image contents. The repository should respond to Web pages that list the search results that match the criteria. The pages provide the courseware creator with a complete view of the matching results (brief descriptions and small picture of each image object). With the interface on the page, the creator can identify and retrieve image objects of particular interest.

### *Web-Based Image Editor and Learning Asset URI Generation*

For viewing and editing a specific image, Web-based repository should provide DICOM image editor component that could be plugged into a browser. With the component, the creator can adjust the presentation (scaling, window level, contouring, measurement, and annotations) of the image on the browser. After image adjustment, a uniform resource identifier (URI) is generated to represent the presentation state (PS)[8] of the image. This generates a teaching asset represented by the URI. The URI will be forwarded to LMS as a linking point for the content in the LMS courseware. After the authoring processing described on the image editing page is completed, the learner can view the courseware in the LMS and can retrieve the asset from the repository through the URI in the courseware. It is the learning asset (the image with PS authored by courseware creator) and not the raw image that is provided to a learner. With the presentation assigned to the image, the creator can share their view of clinical images to a learner.

### *Developing and Testing Environment*

The medical image content repository must have the ability to handle DICOM data objects and support DICOM network services. To accomplish those functionalities in the content server, we chose a free and open source library (UCD DICOM Network Protocol, University of California, Davis, CA, USA) to handle the DICOM protocols. Some modifications of the library were made for use in Borland C++ Builder (BCB). The DICOM network services and DICOM image editor were packaged in the BCB developing environment as Microsoft COM automation objects, so that they can be used in Web server and browser. We chose the Microsoft Internet Information Server as our Web server. Web pages and scripts were developed in Microsoft.Net environment, and we chose Microsoft SQL as our database server. Currently, there are many commercial LMSs available for designing courseware and setting the contents of a course. Two LMSs are available in our department (Blackboard developed by Blackboard Inc., Washington, DC, USA, and E-Campus developed by 3probe, Taipei, Taiwan). Both LMSs were used to test the integration with our content repository. Currently, no commercial LMSs have an interface that allows integration with a content repository, and therefore, it is necessary to customize the LMS to allow the integration and authentication tasks.

# RESULTS

Here we present the functionalities of our Web-based clinical content repository and the processes for the generation of medical image contents for e-learning. In the process, image contents would be generated and stored in our repository, and the courseware using the contents would be set in the LMS. As in this demonstration, it is convenient to promote medical image in PACS for learning in LMS.

## Query Interface of Repository Search Portal

In our LMS (Blackboard LMS), we have constructed a hyperlink "Medicine Image Repository." This links to the search portal of our repository (Fig. 3).

All query conditions were shown inside the red dotted-line area in Figure 3. Users can search clinical contents by using the portal pages. They can query what they are looking for by giving specific conditions, such as name, ID, age, sex, and performed procedure to the interface. After clicking the "Search" button with the query conditions, the system will return a "matching result list."

### Matching Result List

When the Web server received the query conditions, it will search both the repository database by SQL statements and PACS server by DICOM query protocols. The Web server will show the list of results matching with the query condition. Figure 4 is the matching result list. In this list, one can select a specific series of images for display (see Fig. 5). Note that both the results stored in the repository and PACS server are displayed in this list. If the series of DICOM images that meet the conditions are not yet stored in our repository, those images will be retrieved from the PACS server and stored in the repository using DICOM retrieve protocols.

### Image Editing Page

Using the Web-page interface displayed in Figure 5, users can click and select a specific image for editing. After the selection of one specific medical image, the Web page will call an "ActiveX plug-in editor" to display the selected radiography image, and the user can edit the image with the ActiveX plug-in editor. The editor provides enlargement, gray level adjustment, annotation, etc., basic functions (see Fig. 6).

### Learning Asset Page

After submitting the modifications of images and patient information, a URI will be generated to represent the adjusted results. This URI is an HTML-based asset for medical education (Fig. 7). The URI is forwarded to the LMS as a linking point for the content to the LMS courseware.

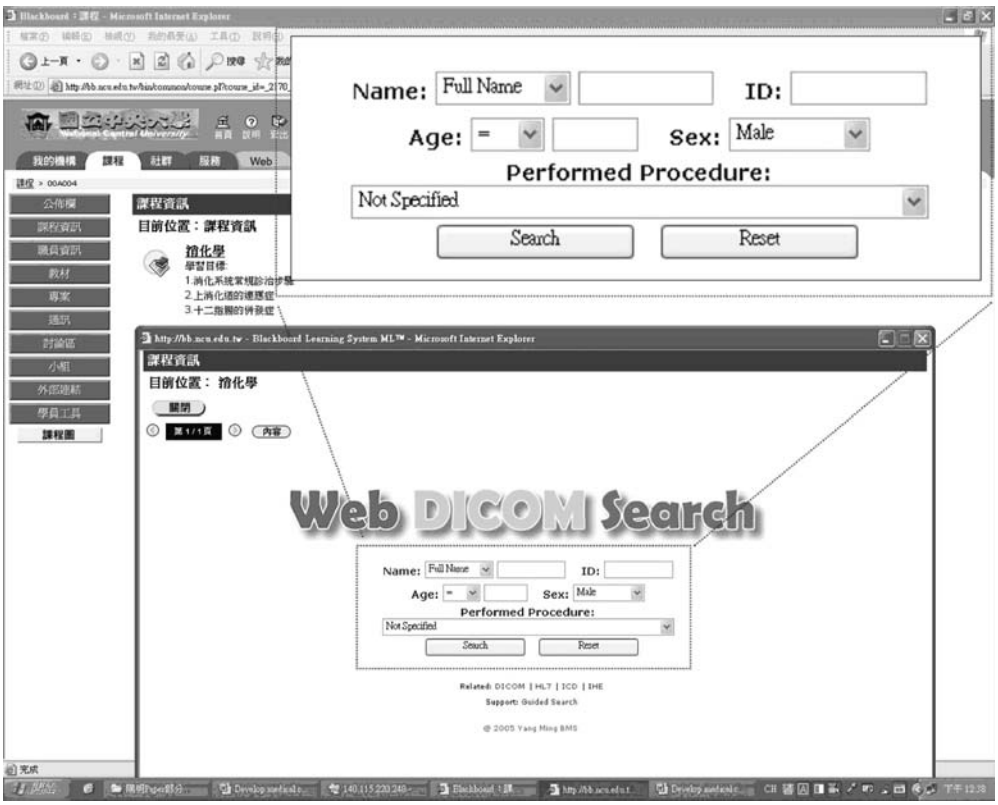


**Fig 3. The homepage of the Web DICOM Search System and query condition items in the Web interface.**

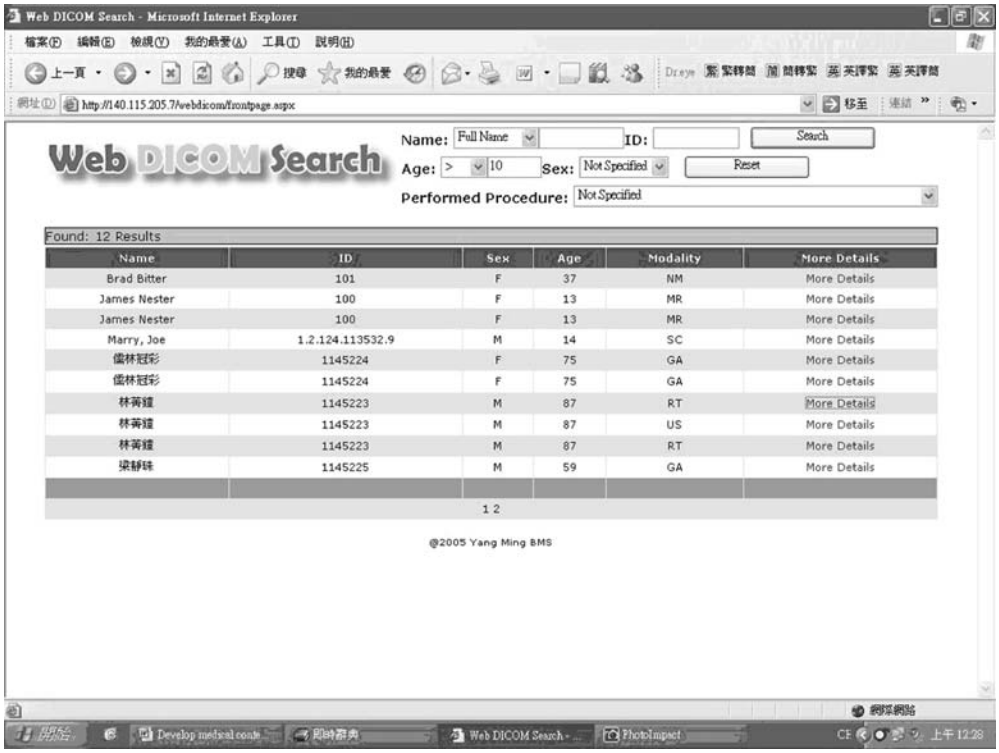


**Fig 4. The matching result list.**

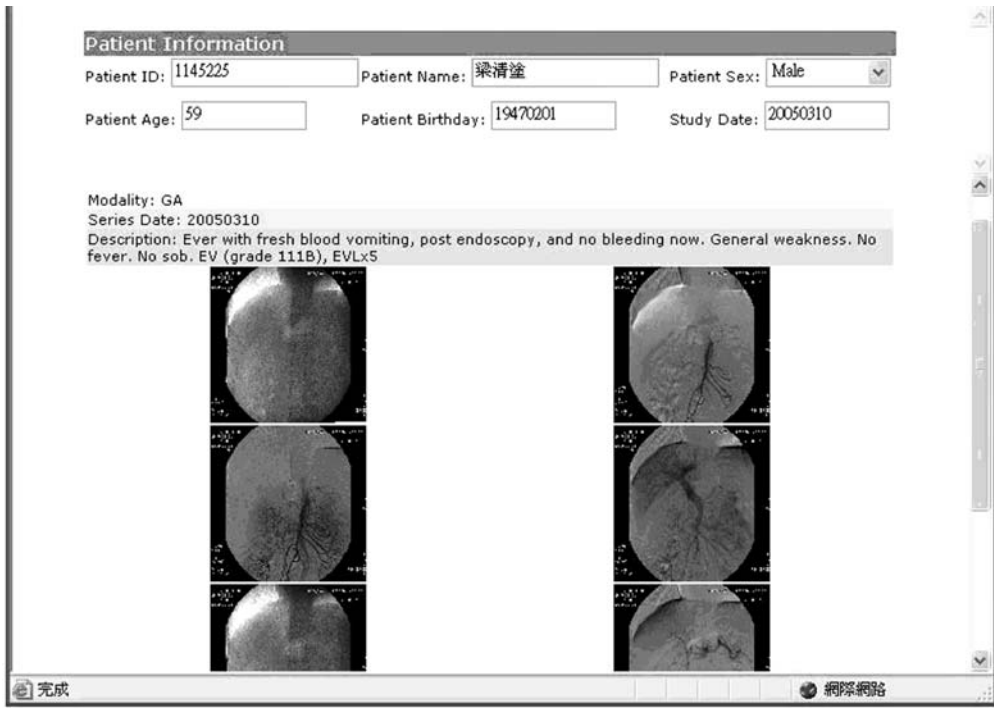


**Fig 5. Patient information and a series of his/her medical images.**

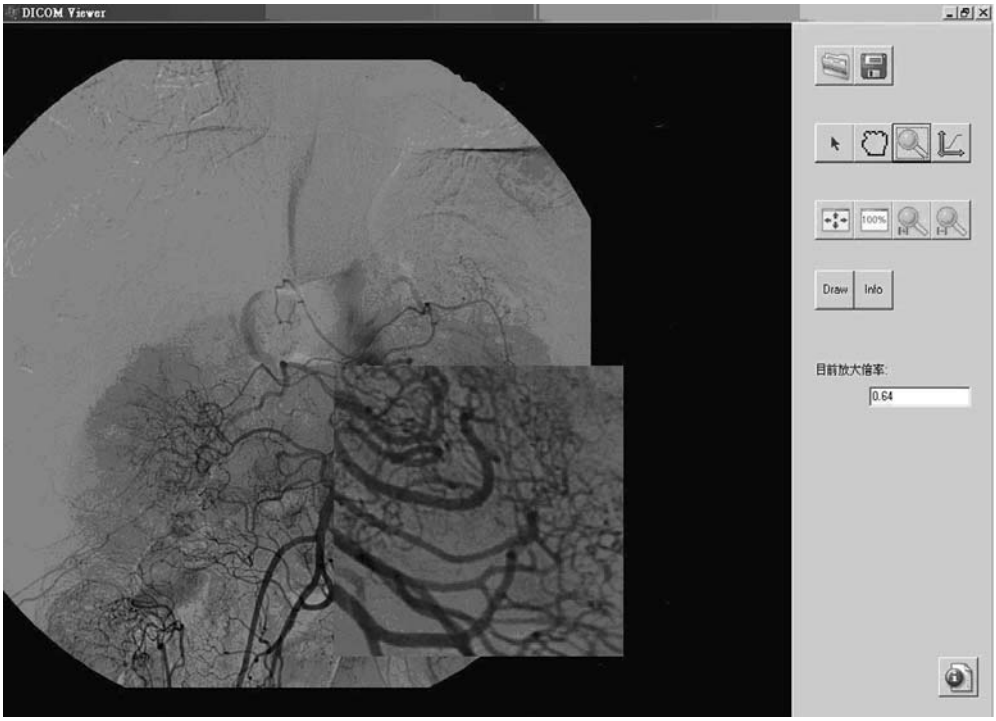


**Fig 6. ActiveX plug-in editor for adjusting image size, gray level, and adding annotations.**

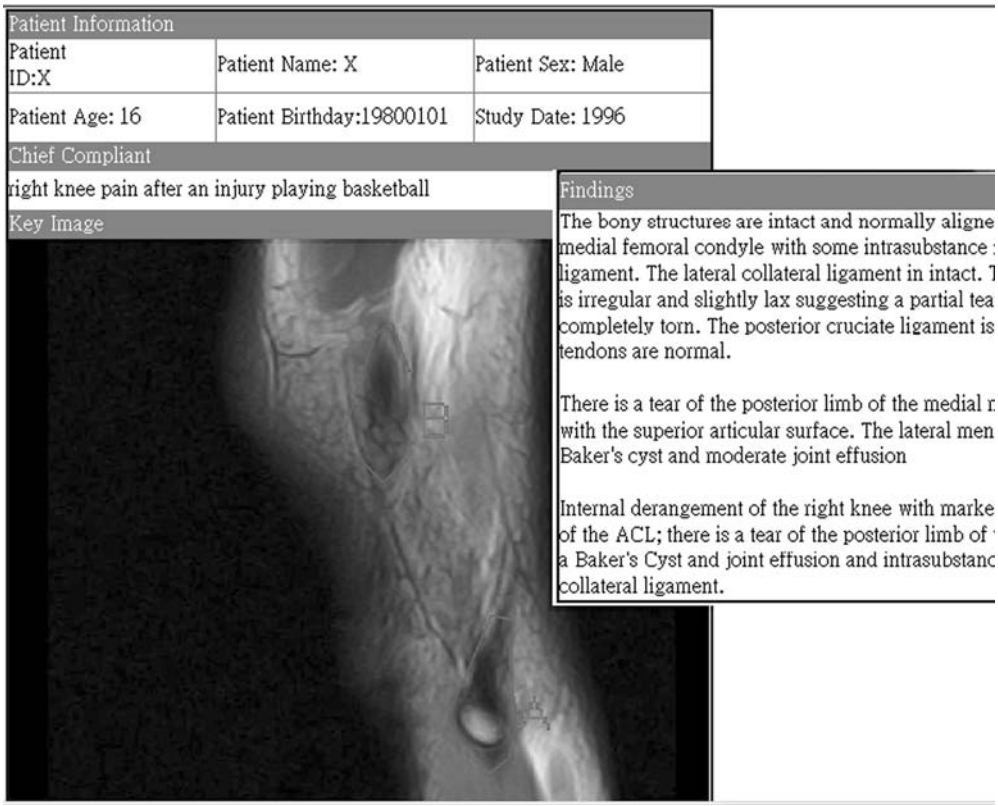


**Fig 7. A learning asset in our content repository.**

## DISCUSSION

### Interaction and Integration of Content Repository and E-Learning Platform

In the domain of e-learning, IMS has adapted the Web solution for integration. As demonstrated in this paper, we can edit medical images in a browser and generate Web-based medical image contents. The Web contents would be stored in our content repository. The URI of the Web content will be passed to the courseware in the LMS when tutors are designing teaching materials. Consequently, the learner can study the image contents assigned in the courseware within the LMS. Using http hyperlinks might be a suitable and the simplest way for system integration. Web-based solution might be the proper means to expand the usage of PACS and reduce the overheads for system integration. Through the interaction of browser and Web server, the core functionalities (edit, submit, search, gather, etc.) of IMS-defined digital repositories are accomplished. All these functionalities can be implemented within one single Web server. Although DICOM is well accepted in the domain of medical image examinations, PACS system integration is not an easy task. In PACS, separate systems are working together based on DICOM protocols (storage, query, and retrieve, etc.) to archive clinical network workflow in a radiology department. It is much easier to expand and modify the functions in a single Web server than to modify separate systems in PACS for new requirements.

In the feature, Web services would be a proper means for integration and archiving interoperation between systems. In our study, we have packaged DICOM library as components that can be used on Web browser and Web server. It is not very difficult to modify the library to support Web services for searching and exploring medical images in PACS. However, IMS has just announced general Web services base profiles.[9] The detail protocols and interoperations between LMS (or LCMS) and content repositories have not been specified currently. Moreover, the LMSs in our department do not support such Web services yet. Content repository that supports Web services for integration might be implemented and investigated in the next step of our research.

### The Differences Between Image Content Repository and DICOM WADO Server

Although DICOM has defined Web access to DICOM objects (WADO) specifications[7] and provided URI link to access DICOM persistent object, there are differences between the WADO and the Web repository demonstrated in this paper. In our demonstration, pure JPEG images and HTML Web pages were stored in our content repository. For learning, original DICOM images are not necessary for a learner. We can respond pure Web pages to the learner. According to WADO specifications, WADO server should have the ability to respond both DICOM and JPEG images to the browser. Clinically, it is convenient that radiologists retrieve DICOM object to browsers and use plug-in DICOM viewer to view and adjust images. Consequently, we must store DICOM image objects in a WADO server. Conventional PACS server or WADO server stores and manages DICOM persistent object. However, our Web-based image repository keeps and handles Web pages. For learning, it is important that teachers and learners can share the same view of image contents. It is the adjusted images and findings generated by teachers and not the original medical images that we should provide to learner for learning. Moreover, it could be easily accomplished if we stored the adjusted images and findings as HTML and JPG formats in the Web-based content repository. Following DICOM WADO specifications, we could use http request with presentation parameters to acquire medical images with specific display format. However, that would be much more complicated in this case for handling the PS and dynamic generation of JPEG images for e-learning.

### Security Issue about Image Content Repository

As a clinical content repository, secure protection of clinical data is very important. All the security requirements (user authentication, access control, secure network transportation, and de-identification of clinical content) should be further considered in our content repository. As Web server is now used in many different domains,

these security issues are important. We can adapt those well-accepted Web security solutions in our content repository in a straightforward manner. Currently, most of the PACS were constructed and used in the well-protected Intranet environment. If we want to expand the usage of PACS on the Internet, we would face and have to overcome the security issues. Although DICOM has announced the security standard since 2003, few of the running hospitals have constructed those security specifications (digital signature, secure transportation, de-identification, etc.). PACS is a distributed system; it is therefore very difficult to upgrade all systems in PACS to fulfill the security requirements concurrently. Without the security protection, it is not suitable to expand the usage of PACS directly. Many usages of digital medical image, such as training and education, consultation, and healthcare information integration between departments, are not confined in a local network. As demonstrated in this paper, a Web solution is suitable for integration and expanding the usage of PACS. Moreover, it is much easier to construct the security protection on a single Web server than that which upgrades the security requirements on all the systems in PACS.

## CONCLUSIONS

This paper demonstrates a preliminary result on the construction of a medical content repository for e-learning. The content repository is a gateway system that can integrate with the standard PACS used in clinical departments. As in many other domains, digital contents would be generated in their daily workflows. The contents might have specialized format and are stored in the domain-specific systems. For the purpose of training and learning, a gateway system is essential for transforming and managing those domain-specific contents, so that it can be used for commercial learning or knowledge management systems. As we have demonstrated in this paper, a Web solution is a suitable and perhaps the simplest means to fulfill this purpose. Through the Web expansion of our system, user can easily search the medical images stored in PACS and generate corresponding Web pages with medical image content for e-learning. Our research has provided preliminary results on the integration of medical image content repository with commercial LMSs. The integration of medical informatics and e-learning systems could be employed in many advanced applications (training, knowledge management, telemedicine, home-care, etc.). This is worthwhile for further investigation and consideration to develop an easy, powerful, and secure solution for constructing clinical content repository.

## ACKNOWLEDGMENT

This study is supported by the CAISER, University Systems of Taiwan (UST).

## REFERENCES

1. HIMSS and RSNA IHE Integration Healthcare Enterprise. IHE Technical Framework Volume I Integration Profiles. Available at: http://www.ihe.net/Technical_Framework/upload/ihe_tf_rev6.0ft_vol1_2005-05-20.pdf. Accessed December 29, 2005
2. IMS Digital Repositories Interoperability—Core Functions Information Model. Available at: http://www.imsglobal.org/digitalrepositories/driv1p0/imsdri_infov1p0.html. Accessed December 29, 2005
3. Wahle, A, Bultjes, JH, and et al.: DICOM-integration in a heterogeneous environment. In Proc. 18th Int Conf. IEEE Eng Med Biol Soc 1228–1229, 1996
4. Pavlopoulos SA, Delopoulos AN: Designing and implementing the transition to a fully digital hospital. IEEE Trans Inf Technol Biomed 3:6–19, 1999
5. Kimura M, Ohe K, et. al: MERIT-9: a patient information exchange guideline using MML, HL7 and DICOM. Int J Med Inform 51:59–68, 1998
6. DICOM Standard Part 4: Service Class Specifications, National Electrical Manufacture Association, USA, 2004
7. DICOM Standard Part 18: Web Access to DICOM Persistent Objects (WADO) Service Class Specifications, National Electrical Manufacture Association, USA, 2004
8. DICOM Standard Part 3: Information Object Definitions A.1.2 IOD Entity-Relationship Model: Presentation State IE
9. IMS Global Learning Consortium: General Web Services Public Draft Specification. Available at: http://www.imsglobal.org/gws/gwsv1p0pd/imsgws_profilesv1p0pd.html. Accessed December 29, 2005