國立交通大學

資訊學院　資訊學程

碩士論文

DICOM 醫療資訊應用 Partial DRM 於雲端科技環境

Applied Partial DRM Protection for DICOM Annotated Information in Cloud Environment

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中華民國一百年十二月

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摘要

目前已成熟的雲端技術環境，為現代人提供了更好的網絡服務品質，使我們能多方利用網際網路的便利性。筆記型電腦和智慧型手機為常用到的電子產品，使用者能隨時隨地享用網際網路的服務。這種便利的網路服務，產生更多的有價值的線上應用程式，提供更簡單的方式，存取、瀏覽網路上的資源，如社交，新聞，照片，銀行系統，等等。

醫學界也提供使用者網路應用程式。DICOM 是醫療系統的信息交換的標準格式。在網路上也有許多與DICOM有關的應用程式。

快速增長的網際網路引發了安全和隱私問題。數位內容保護成為一個重要課題。如果數位內容的安全機制沒有做好，會引發未被授權的的使用，存取重要資訊，損害擁有者的權利。DRM（數位版權管理）是為了控制、保護、限制數位內容的應用。

本論文提出了一個Web應用系統解決方案，提供使用者線上存取 DICOM 資訊，並能搭配局部 DRM 安全機制設計。使用者可以透過個人的行動裝備，連結到網路上的應用程式，並查看 DICOM 資訊。這種機制提供了無所不在的環境，讓使用者能方便又快速得到所需的資訊。

Applied Partial DRM Protection for DICOM Annotation Data in Cloud Environment

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Degree Program of Computer Science

National Chiao Tung University

Abstract

Mature cloud technology environment provides good quality of internet and network service which allow us to do things more convenience online. Laptop and smart phone is an example of majority device which provide ubiquitous mobile computing that keeps people connected to the internet. This convenient environment service triggering more useful online applications which provide people many easy ways to access online contents and resources, such as social networking, news, photo management, banking system, and many more.

Medical World also offered some online applications to do their operation. DICOM is the standard format used to exchange information in medical systems. There are also many online applications which are related to DICOM.

Rapid growth of internet results in security and privacy issue. Digital information protection becomes an important subject. There are possibilities for unauthorized access to retrieve the content information for unknown purpose which unintended by the owner if the security mechanism is not well applied. DRM (Digital Rights Management) is designed to control, protect and limit the use of digital content. It is impractical using fixed DRM in all digital contents such as digital medical image.

This paper proposed a web application system solution that offers end-user to access DICOM information online with partial DRM security mechanism design. User can use their personal mobile device to connect to the application and viewing to DICOM information becomes more convenience, since it can be done anytime anywhere.

Acknowledgement

感謝陳登吉教授耐心的指導，在研究的過程中，時時給予建議，正確的方向，才能順利完成本論文。

同時也要特別感謝博士班學長鎮宇的指導與幫助以及同學簡宏任的互相鼓勵。

最後，要感謝我的家人，在求學的這一段期間內給予的支持與鼓勵，特別要感謝我的父母親對我的照顧與付出，才能成就我的理想，感謝您們!!

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1 Introduction

1.1 Background

Computer information and technology has becomes a crucial part in medical world. Hospitals, clinics, health departments and other facilities that provide health care are utilizing the information management practices for administration functions and resources information. Cloud computing at this context provides functionality and environment to managing data and information in a ubiquitous manner supporting several platforms, systems, and applications. Such systems provide efficiency and convenience, but also can lead to serious information leakage issue if the related permission and security mechanism is not well designed and applied.

Nowadays in medical world, information is stored in digital and multimedia format, for example internal system that manages the hospital administrative and operation have its data stored in their own database system. Images of X-rays, CT scans, and MRIs can be seen from a computer, which means that there is no need for radiology service to print every image after scanning, and they also can maintain the data on their system for further analysis. DICOM (Digital Imaging and Communications in Medicine) has become an essential component for the integration of digital imaging in medical systems.

DICOM file contains patient information (for example name, id, birthday, sex, etc) and annotations data. After examine the patient, medical staffs (such as doctors, nurses, etc) can annotate some information on the related file, for example current patient condition which is not convenient to give out to other party, professional medical knowledge which is not intended to share to everybody, etc. The HIPAA (Health Insurance Portability and Accountability Act) Privacy Rule, which enacted by US Congress and signed by US President in 1996, provides federal protections for personal health information held by covered entities and gives patients an array of rights with respect to that information. At the same time, the Privacy Rule is balanced so that it permits the disclosure of personal health information needed for patient care and other important purposes [7]. At this situation, DICOM data protection is very important for both patient and related medical staffs. Without proper protection, the information inside can be retrieved by anyone, which lead to security and privacy issue.

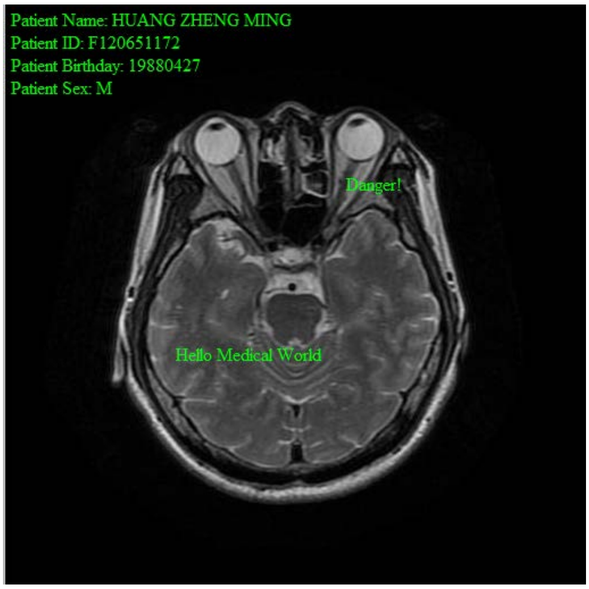


Figure 1. DICOM with Patient Information and Additional Annotation Information

Suitable information should be shared to suitable person. Choosing protection method using full fixed DRM (Digital Rights Management) is impractical since its protection mode is to protect all information inside. Some information might be intended to be exposed to public, and not all information is intended to be seen by user once he has the permission. This paper proposes using partial DRM approach for DICOM information protection. We can choose which user can see which contents information. Therefore, information sharing can be more efficient since different user may have different view of information; without have to worry that the patient's information and medical staff's professional knowledge were retrieved by unintended party.

With full DRM protection:

1. Granted user can view all the information on the file, even some part of the information is not intended to be exposed to the related users.
2. Not granted users can't view information on the file at all, even some part of the information is intended to be exposed to public.

With partial DRM protection:

1. Granted user can only view the information which is intended by the owner selection.
2. Not granted user still can view the public information (no security and privacy issue)

1.2 Motivation

Annotated data on DICOM contains critical information. With partial DRM, partial content protection and partial content sharing can be achieved. For example, during seminar which discussing dangerous disease (ex. AIDS), when showing the related DICOM file, the patient information can be hidden and protected. In this way, different users have different view on the DICOM file contents.

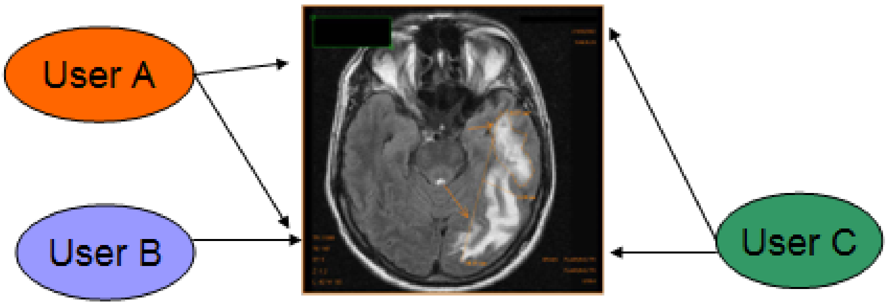


Figure 2. Different users have different view on the DICOM file contents

Using this way, medical staffs can only view the partial encrypted DICOM annotation information on their workstation. They can't view it on PC at home or on laptop during business travel, since DICOM file, partial DRM engine, and annotator is located inside his workstation. By putting contents on the platform provided by web application with network infrastructure technology support, users can use their devices (such as laptop, smart phone, etc) to view the DICOM information anytime anywhere.

At 2010, author [1] has proposed a partial DRM solution on DICOM information protection. At 2011, author [2] has proposed a DICOM compatible annotator tool. This paper extends and integrates the DICOM annotated information with partial DRM solution in cloud environment where critical information protection and sharing with proper security mechanism in ubiquitous manner can be achieved.

1.3 Goal

This paper objective is to build a web based solution which has "sharing made easy platform" for DICOM annotated information, with proper security mechanism applied.

- By applying partial DRM technique, we can achieve partial content sharing security, so that users can only access information which admin has granted to them.
- Information accessing made easy since content is on the Cloud

1.4 Chapter Summary

Chapter 1, “Introduction”, describe this paper’s backgrounds, motivations, and goals.
Chapter 2, “Related Works”, describe related discussions and literature review.
Chapter 3, “System Analysis and Design”, describe the system requirement, and how the system was designed and implemented to fulfill our objectives.
Chapter 4, “Experiments and Results”, contains the demo of the implemented system
Chapter 5, “Conclusions”, describe this paper conclusions and future work

2 Related Works

2.1 DICOM Introduction

DICOM (Digital Imaging and Communications in Medicine) is standard format for handling information in medical imaging which is now widely adopted by hospitals. It is developed by ACR (American College of Radiology) and NEMA (National Electrical Manufactures Association) to aid the storage, distribution, and viewing of medical images contents, such as CT scans, MRIs, and ultrasound.

DICOM standard is released because experts realized that improvement is needed for the better transition and compatibility of the old standard output image format which produced from computed tomography or magnetic resonance imaging devices. Now the DICOM standard enables the integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into a picture archiving and communication system (PACS).

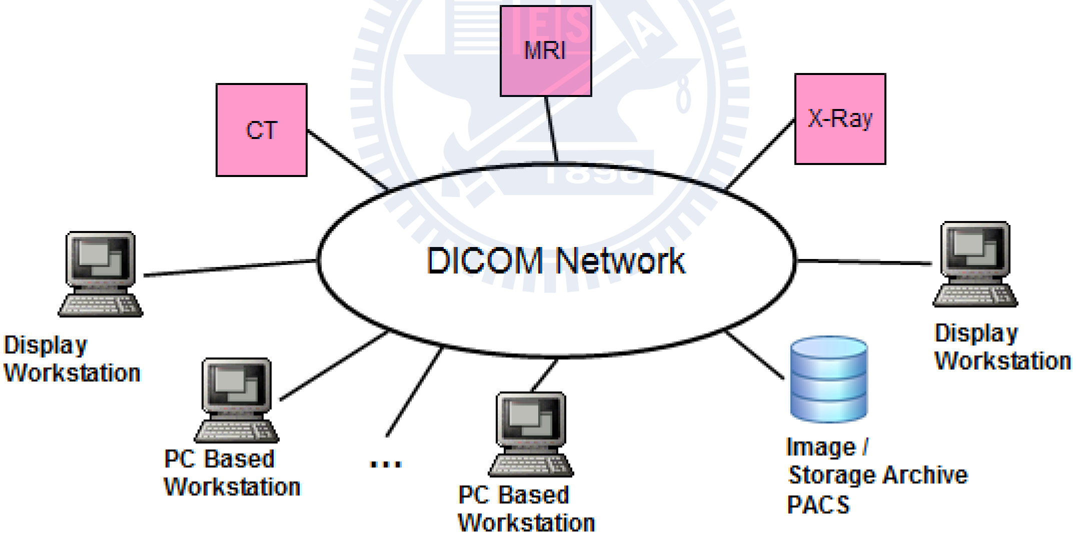


Figure 3. DICOM Network Overview

Below are the steps of how the DICOM is created [1]

1. A CT (Computed Tomography) scan is performed
2. The scanner constructs a set of images (study)
3. The scanner sends the study to a PACS
4. A workstation queries the PACS and retrieves the study
5. Reconstructions or reformats

DICOM data element can be divided into 4 parts, which are TAG, VR (Value Representation), Value Length, and Value Field. Those data elements are represented by HEX. TAG is combination of Group ID and element ID. VR represent the related data element type, for example PN stands for Person Name, DA stands for Date, TM stands for Time, UI stands for UID (Unique ID), etc. VR is an optional field which is used during transfer syntax whether explicitly or implicitly shows the VR information. Value Length represents the length of Value Field, and Value Field itself represents the real data element value.

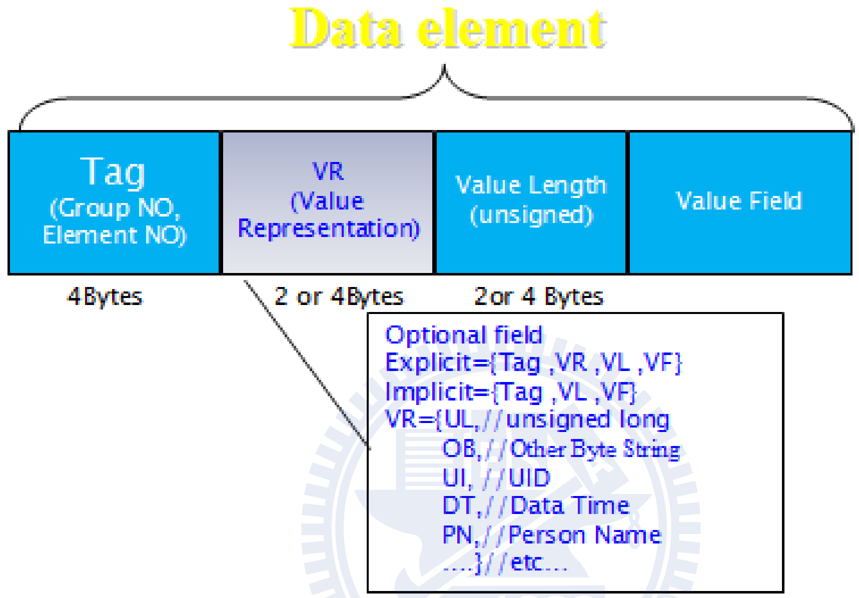
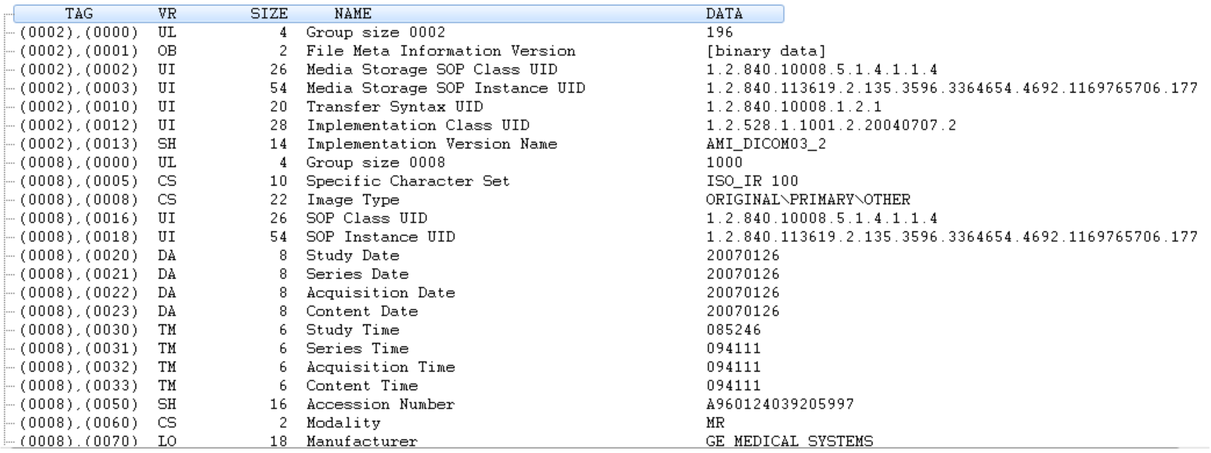


Figure 4. DICOM Data Element Structure

VR Name	Definition
DA	Date
DT	Date Time
FL	Floating Point
LO	Long String
PN	Person Name
TM	Time
SQ	Sequence of Items
OB	Other Byte String
UI	Unique Identifier (UID)
UL	Unsigned Long
US	Unsigned Short
…	

Table 1. DICOM Value Representations (Source: DICOM Spec. 5-Table 6.2-1)



TAG	VR	SIZE	NAME	DATA
(0002),(0000)	UL	4	Group size 0002	196
(0002),(0001)	OB	2	File Meta Information Version	[binary data]
(0002),(0002)	UI	26	Media Storage SOP Class UID	1.2.840.10008.5.1.4.1.1.4
(0002),(0003)	UI	54	Media Storage SOP Instance UID	1.2.840.113619.2.135.3596.3364654.4692.1169765706.177
(0002),(0010)	UI	20	Transfer Syntax UID	1.2.840.10008.1.2.1
(0002),(0012)	UI	28	Implementation Class UID	1.2.528.1.1001.2.20040707.2
(0002),(0013)	SH	14	Implementation Version Name	AMI_DICOM03_2
(0008),(0000)	UL	4	Group size 0008	1000
(0008),(0005)	CS	10	Specific Character Set	ISO_IR 100
(0008),(0008)	CS	22	Image Type	ORIGINAL\PRIMARY\OTHER
(0008),(0016)	UI	26	SOP Class UID	1.2.840.10008.5.1.4.1.1.4
(0008),(0018)	UI	54	SOP Instance UID	1.2.840.113619.2.135.3596.3364654.4692.1169765706.177
(0008),(0020)	DA	8	Study Date	20070126
(0008),(0021)	DA	8	Series Date	20070126
(0008),(0022)	DA	8	Acquisition Date	20070126
(0008),(0023)	DA	8	Content Date	20070126
(0008),(0030)	TM	6	Study Time	085246
(0008),(0031)	TM	6	Series Time	094111
(0008),(0032)	TM	6	Acquisition Time	094111
(0008),(0033)	TM	6	Content Time	094111
(0008),(0050)	SH	16	Accession Number	A960124039205997
(0008),(0060)	CS	2	Modality	MR
(0008),(0070)	LO	18	Manufacturer	GE MEDICAL SYSTEMS

Figure 5. Example of DICOM Data Element Content

2.2 Cloud Technology

Cloud computing is Internet-based computing, whereby shared resources, software, and information are provided to computers and other devices on demand. It is an emerging new computing paradigm for delivering computing services. Cloud computing users pay the service provider only for what they use.

Cloud computing can be categorized into 3 major which are:

- SaaS (Software as a Service)
  A complete application offered as a service on demand. The related software runs on the cloud and services multiple end users. For example: Social Network (facebook, twitter), Google Services (Google Map, Google Docs, Google Calendar), etc. Some companies who charge their users for using SaaS: Salesforce.com (Cloud CRM), NetSuite (Cloud ERP).

- PaaS (Platform as a Service)
  The provider provides a platform for developer to build their own services. For example: Google Apps engine (Java, Python), Microsoft Azure (.NET Framework).

- IaaS (Infrastructure as a Service).
  Infrastructure as a service delivers basic storage and compute capabilities as standardized services over the network. Service provider provides some hardware servers, storage systems, switches, routers, etc. AWS (Amazon Web Service) EC2 is a widely adopted charged IaaS by worldwide.

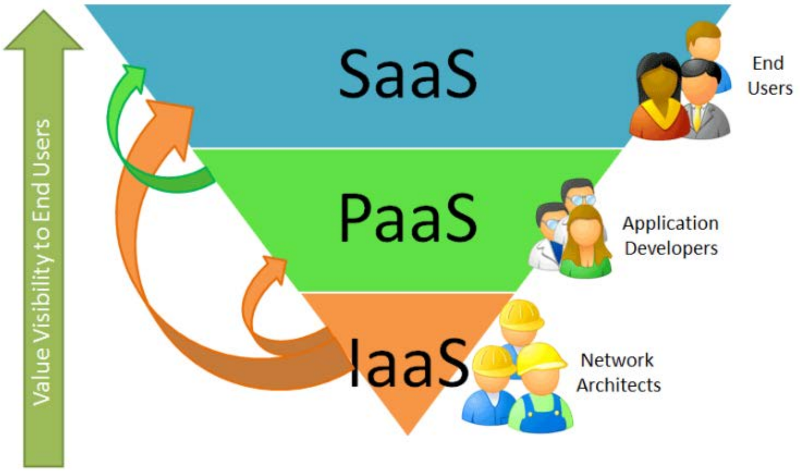


Figure 6. Types of Cloud Computing and Its User
(Image source: http://hrushikeshzadgaonkar.wordpress.com)

Based on the security level, cloud computing can be categorized into three types:

- Private Cloud

  This cloud hosted within the boundaries (firewall) of the organization which is managed by the enterprise and considered more secure since it has full control over the resources. But to build and maintain private clouds, organization is required to do some hardware investments and the cost can be exceeding the public cloud.

- Hybrid Cloud

  Combination of private and public cloud but still has the firewall to distinguish between them. An organization provides and manages some resources in-house and has others provided externally.

- Public Cloud

  Service is hosted and opened for use by general public. It fully hosted and managed beyond firewall. Cloud user can be individuals, corporations and organizations. For example Amazon’s Web Services and Google App engine.

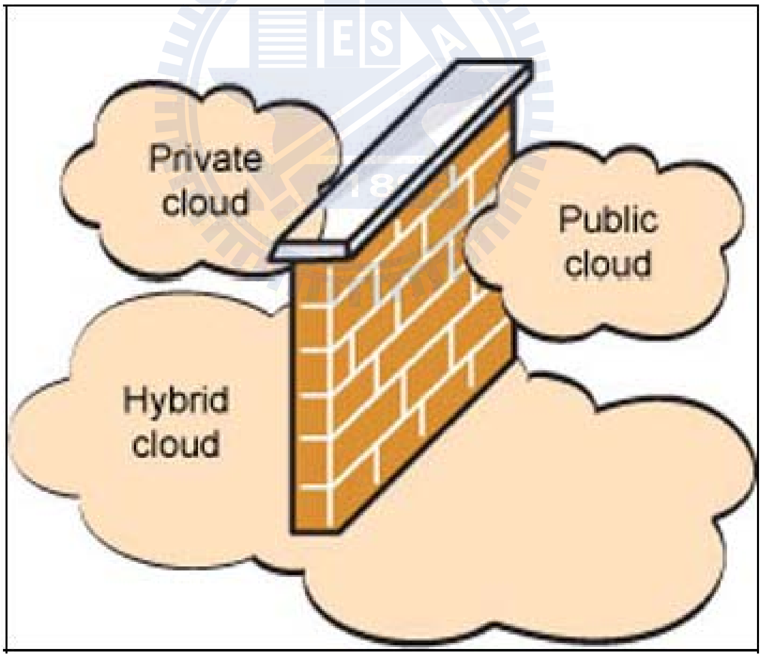


Figure 7. Types of Cloud Based on Security Level
(Image source: http://www.wifinotes.com)

2.3 Previous works

Author [3] at July 2010 proposed web based solution to store and query the DICOM information. This proposed solution does not cover protection mechanism against DICOM contents information, which can lead to security and privacy issue. Author [4] at June 2011 proposed a secure cloud gateway to access DICOM archive. This proposed solution does not offer sharing mechanism. Some part of DICOM information can't be shared to groups of specified people.

At previously mentioned this paper extends previous team works to integrate DICOM annotated information with partial DRM solution in cloud environment. Author [2] at July 2011 proposed a DICOM file compatible annotator tool solution approach. Medical staff can use the annotator tool to annotate some important information (for example current patient situation, medical staff knowledge, etc) in the DICOM file. Author [1] at July 2010 proposed a partial DRM solution for DICOM file which intend to partially protect the DICOM critical data (including the annotation information) against unauthorized access which will be needed during DICOM file transfer, which will be referred as V1 solution in below image and next statement.

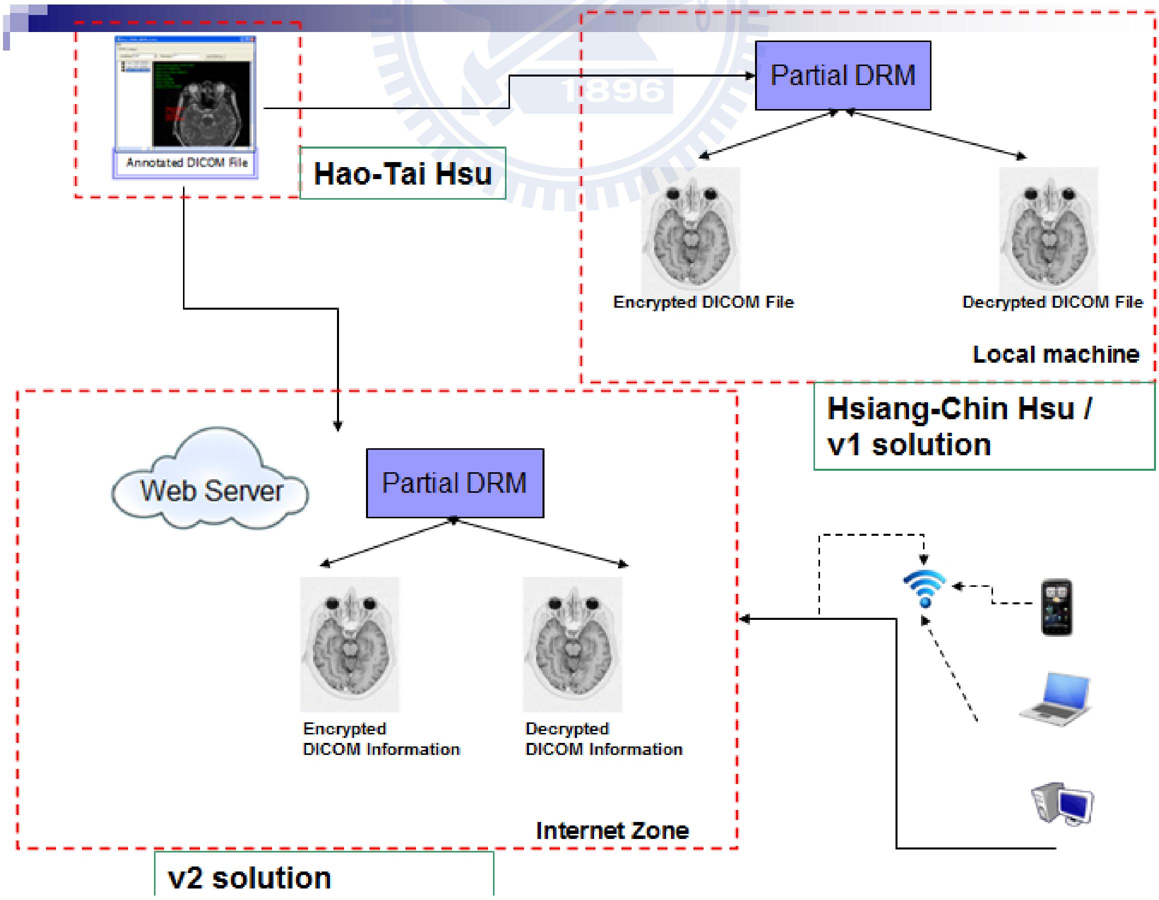


Figure 8. Previous Team Works and Proposed Solution

Below is table which compares the difference between V1 and V2 solution.

V1 Solution	V2 Solution (Proposed)
Goal is to partially protect critical data against unauthorized access (based on HIPAA standards) (ex. Needed during DICOM file transfer from hospital to hospital)	Goal is to make convenience access on DICOM information (anytime anywhere) with protection and sharing mechanism applied
Both input and output is DICOM File. (PACS compatible)	Input (uploaded) file is DICOM file, which the information will be processed and saved in web server database. The output is DICOM information on web browser.
Pascal standalone application on local machine	Java web application on cloud server
Access local intranet DICOM file	DICOM file is uploaded to web server and its information will be accessible from world wide internet.
Users encrypt and view the DICOM file information on his local workstation	Users view the DICOM information anytime anywhere, as long as they got internet access and web browser.
Support local PC machine	Support PC / laptop, and smart phone which have internet connection and built in browser
Majority of the computing effort is on local machine	Majority of computing effort is on cloud

Table 2.　V1 and V2 Solution Comparisons

3 System Analysis and Design

3.1 Requirement Analysis

Our proposed prototype web based system will have some basic features which are:

3.1.1 Upload DICOM file

User can upload DICOM file to the web server. System will read and show the patient information along with annotated information inside DICOM. After choose the protection method and grant related view access permission, user can save the information to database. If the information is protected, system will do data encryption process to ensure the data security which can’t be view before doing the related decryption process.

3.1.2 Protection method and grant DICOM information permission

After upload the DICOM file and system show the related information, user can choose protection method and which information to be granted to which users.

3.1.2.1 Protection Method

On the protection method, system provides three different options. The first one is “All Protect”, which means that all the patient information and annotation data is to be protected (Full DRM method). The second one is “Partial Protect”, which means that user can choose which patient information or annotation data is to be protected. The third one is “No Protect”, which means that there is no need to protect the patient information and annotation data.

3.1.2.2 Policy on granting user permission

For more reasonable requirement design of the related policy, grant permission access of the medical staffs’ list candidates will be based on the medical staff’s related department information and whether the related medical staff has been take care of patient.

Illustration which can be found on Figure 9 shows us that based on the DICOM information which has department information and patient id, system will bring a list of valid medical staff candidates which their department is the same with the uploaded DICOM and they have been take care of the related patient which identified by the patient ID. Based on this valid medical staffs list, admin can choose which user to be granted which DICOM information.

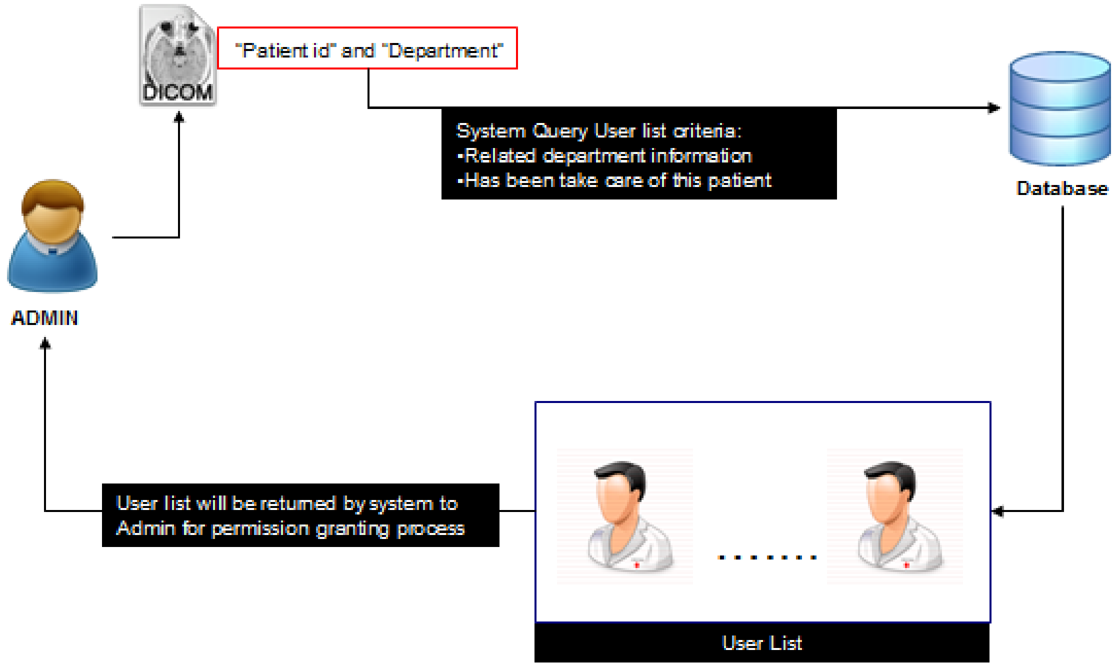

"Patient id" and "Department"
DICOM
System Query User list criteria:
•Related department information
•Has been take care of this patient
Database
ADMIN
User list will be returned by system to Admin for permission granting process
User List

Figure 9. Valid User Lists for Granted Permission Candidate on DICOM information

3.1.3 View DICOM file

After DICOM has been uploaded and the related information has already been saved to web server, including granted view permission, user can login and access the web server to view the DICOM information.

System will show the DICOM information immediately on the browser if the related information is not protected, which considered public information and have no security concern. If the related DICOM information is protected, then system will show “Info is not visible” wording instead of the real information.

When user tries to view the protected information by clicking the “Info is not visible” wording, system will check whether this user has been granted permission to view the protected information. If user has permission to view the related information, system will do the data decryption process, and show the real information in the browser. If user doesn’t have the permission to view the related information, system will not do the decryption process, instead will show “You don’t have permission to view this information” alert message to notify user that he don’t have access to the information.

3.2 Use Case Diagrams

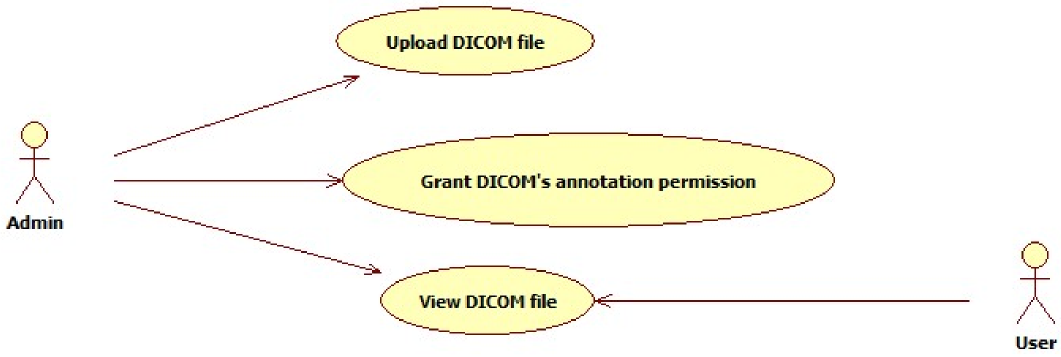


Figure 10. Use Case Diagram

Our system has two actor roles, which are “Admin” and “User” and three functionalities. Only “Admin” role can do the “Upload DICOM file” and “Grant DICOM annotation data permission to other user” action. While both “Admin” and “User” can “View DICOM file”.

3.3 Activity Diagrams

3.3.1 Admin Activity Diagram

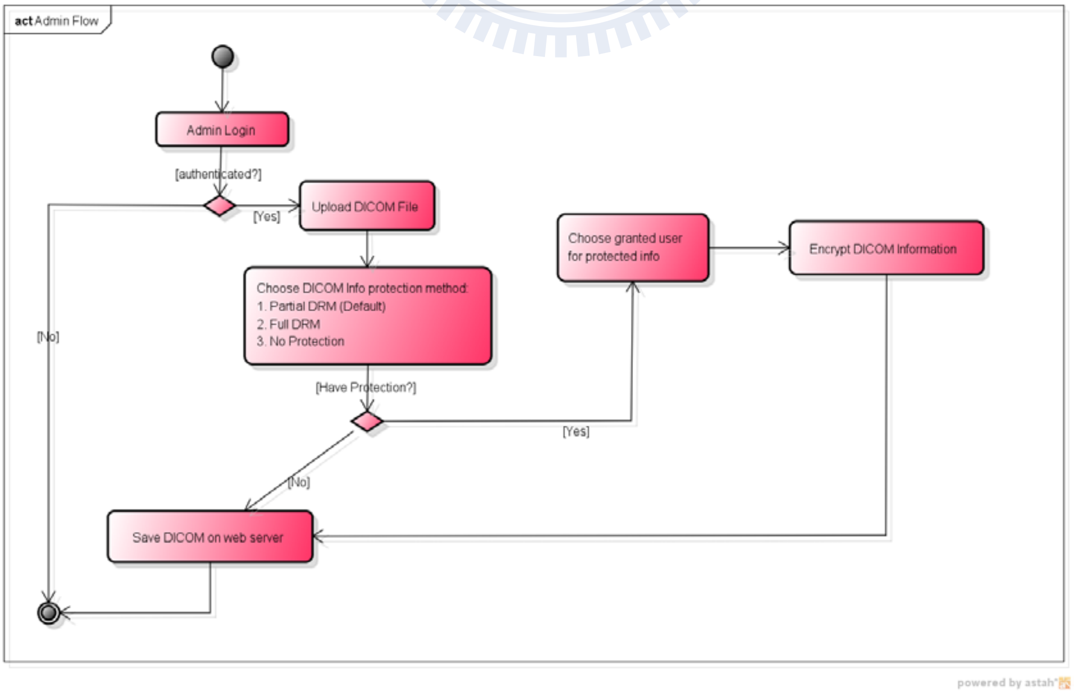


Figure 11. System Admin Activity Diagram Flow

Steps of Admin Activity Diagram:

1 Admin do the login action to the web server

2 System will check whether the user is authenticated to access the web server.

3 If it is authenticated, admin can use “Upload DICOM” action. If it is not authenticated, then system will not allow user to do any operation on the web server.

4 After DICOM file was uploaded successfully, system will ask user to choose the information protection method. Default protection method will be “Partial DRM” which will allow user to choose some part of information to be protected.

5 If there is information to be protected, admin can choose which user to be granted permission for the related information. The valid user list is already discussed on previous “System Requirement” section. After confirm what information to be protected, and which user to be granted the view permission, system will encrypt the related information.

6 Save DICOM information in web server

3.3.2 User Activity Diagram

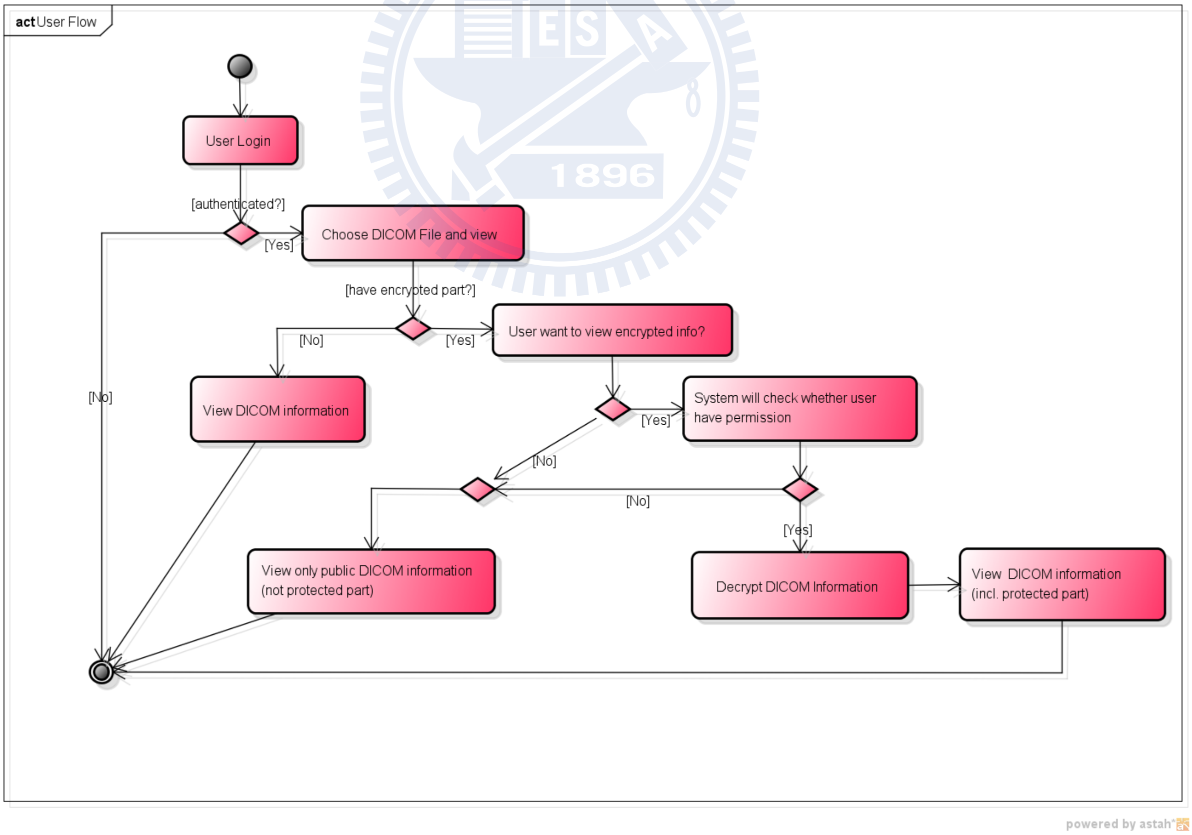

act User Flow
User Login
[authenticated?]
[Yes]
[No]
Choose DICOM File and view
[have encrypted part?]
[No]
[Yes]
User want to view encrypted info?
View DICOM information
[Yes]
System will check whether user have permission
[No]
[No]
[Yes]
View only public DICOM information (not protected part)
Decrypt DICOM Information
View DICOM information (incl. protected part)
powered by astah*

Figure 12. User Activity Diagram Flow

Steps of User Activity Diagram:

1. User do the login action to the web server
2. System will check whether the user is authenticated to access the web server.
3. If it is authenticated, user can use “View DICOM file” action to view the information. If it is not authenticated, then system will not allow user to do any operation on the web server.
4. When showing the DICOM information, if one of the information is protected, then system will show “Encrypted” wording on it.
5. When user click the “Encrypted” wording to decrypt the information, system will check whether the related user has been granted permission to view the related information. If user have the permission, then system will decrypt the protected information, and show the real content to the related user. . If user doesn’t have the permission to view the information, system will not do the decryption process, and keep show “Encrypted” wording.

3.4 Encryption Method

After admin confirm select the protected DICOM information with the granted user access permission, system will save all the information in database. We assume that the protected information is considered critical and contains sensitive data. Based on this assumption, we need to do additional encryption action when saving the record into the database to make sure the protected information is secured, so that not even the database administrator can determine the information when the information is protected. For example, if the database is hosted at third party vendor’s company, then the database administrator who works at the company will be able to view the data at will if the sensitive information is not encrypted.

For the cryptography mechanism, we choose symmetric-key encryption algorithm, which means the algorithm using the same key for both encryption and decryption method. We using this kind of algorithm because encryption and decryption process only happened on the web server side, and there is no need we share the key to client to do the message encryption.

For the implementation of symmetric-key encryption, we choose AES (Advanced Encryption Standard). AES was announced at November 2001 by NIST (National Institute of Standards and Technology) as the most suitable standard encryption for U.S. government, and it is now used worldwide. It supports combinations of key and block sizes of 128, 192, and 256.

The AES standard has been incorporated into several Java technology offerings. Beginning with the Java 2 SDK, Standard Edition (J2SE) v 1.4.0, the Java Cryptography Extension (JCE) was integrated with the SDK and the JRE. Since then, it has no longer been necessary to install the JCE optional package, since support for strong cryptography is now available as part of J2SE. From a developer perspective, JCE is a higher level of abstraction, and a common set of APIs for newer and different cryptographic algorithms -- without the need to worry about the inner workings of the algorithm.

In current system design, we are using AES encryption method with 128 key block sizes. When saving the record into database, system will determine if the related information is protected. For non-protected information, system will just write the content to the database. For protected information, system will do encryption process with AES algorithm, and save the encrypted information to the database. When granted user request to view the protected information, system will get the encrypted information from database, and do the decryption process.

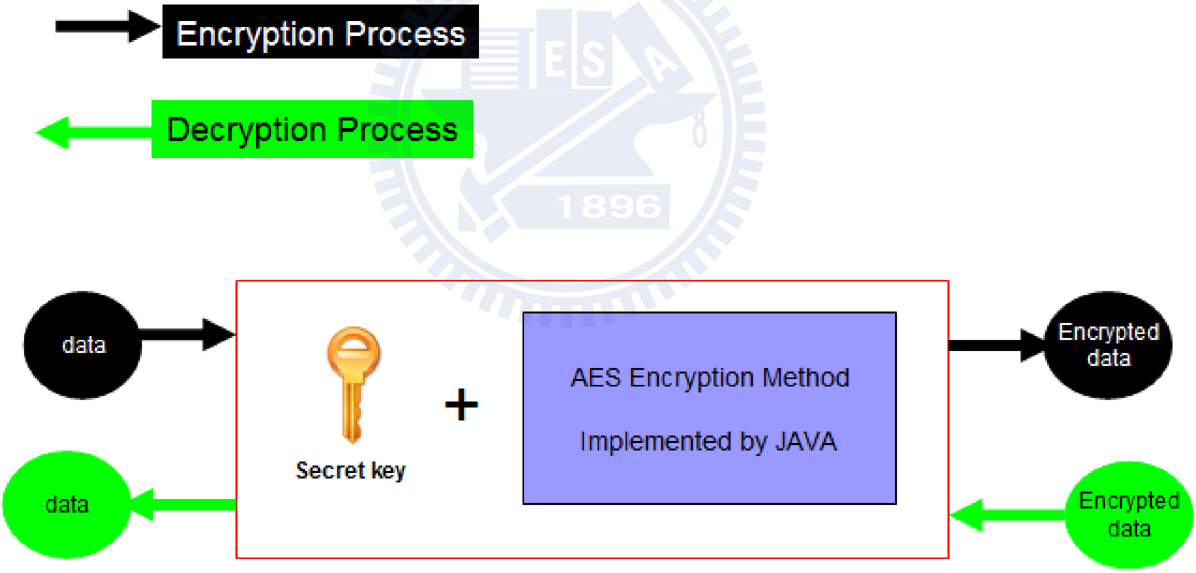


Figure 13. Encryption and Decryption Process

3.5 Database Design

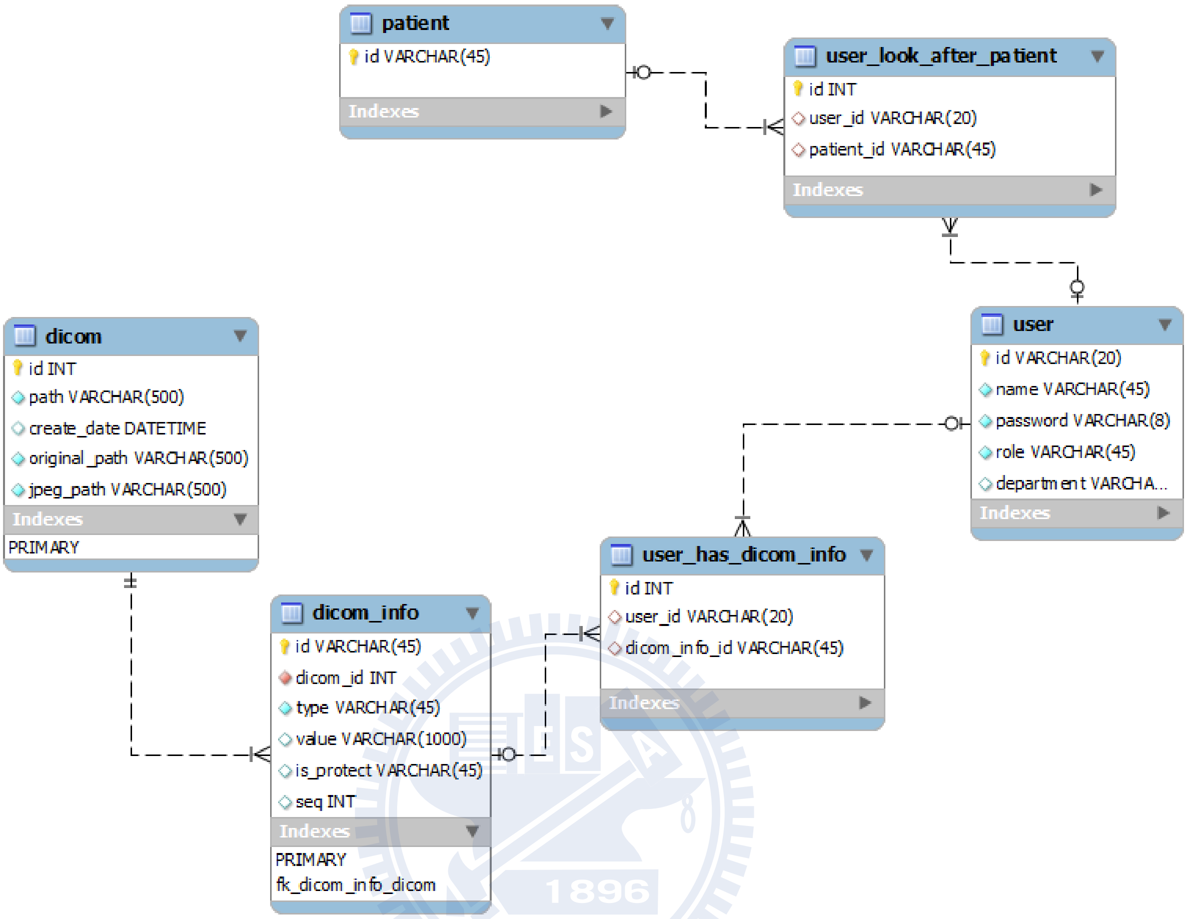


Figure 14. System Table Schema

User and Patient

To determine whether this user is eligible to be granted view permission for protected DICOM information, system will reference the department information in table “USER” and whether this patient has been taken care by the related user, which the information can be found in table “USER_LOOK_AFTER_PATIENT”.

DICOM information and User

One DICOM have a list of information (which includes patient and annotation data). One to Many relationships will be realized by table “DICOM” and “DICOM_INFO”.

For specific DICOM information, it can be protected or not. If it is protected, then the value will be the encrypted string. The table “USER_HAS_DICOM_INFO” contains data of which user can have view access on the protected information. So system will check this table when user tries to view protected DICOM information.

3.6 System Environment

When building the system, this thesis is focusing on using well known freeware license or open source software which has complete documentation of how to install and use with a great community support from the internet.

We choose JAVA as our main language for this thesis, since it comes with a great support of third party (library file which offers commonly used functionality) and proven track of stable application when it comes to web based solution. As an OOP language, with better design and highly reusable code, we can focus on the use case functionality and business logic implementation. For the third party framework, we use Apache Struts for MVC framework, Spring as application framework, Hibernate as OR mapping framework. Those are powerful and well known open source frameworks in Java EE solution.

For DICOM parser, we choose ImageJ (version 1.44) since it is free and open source JAVA code which is compatible with our language platform. It is image processing software which can show DICOM image and parse the information inside based on the DICOM data element standard. It can also convert from DICOM to image file format (ex. JPG, JPEG, TIF, etc). It power and flexibility allow it to be used as a research tool in medical world.

Module	**Software**
Language Platform and Used Third party Framework	Java EE (Enterprise Edition) 6 and JDK 1.6.0_27 MVC: Apache Struts 1.3.10 Application Framework: Spring 3.0.5 OR Mapping Framework: Hibernate 3.2.1 DICOM Parser: ImageJ 1.44
Web Application Server	Sun Glassfish Server 2.1 (Free Edition)
Database	MySQL 5.1 (Community Edition)
Operating System	Microsoft Windows XP Professional Edition
IDE	Eclipse 3.7.0 (INDIGO)

Table 3. System Software List

4 Experiments and Results

4.1 Environment Setup

We need to build the related web application system in an environment which can be accessed by outside world wide user to make sure that our demo which include smart phone device to view the DICOM information through cloud can be executed successfully. By the permission of HTC, I built and install the web application on one of its server farms which is located on DMZ (demilitarized zone) and accessible by outside internet.

4.2 Data preparation

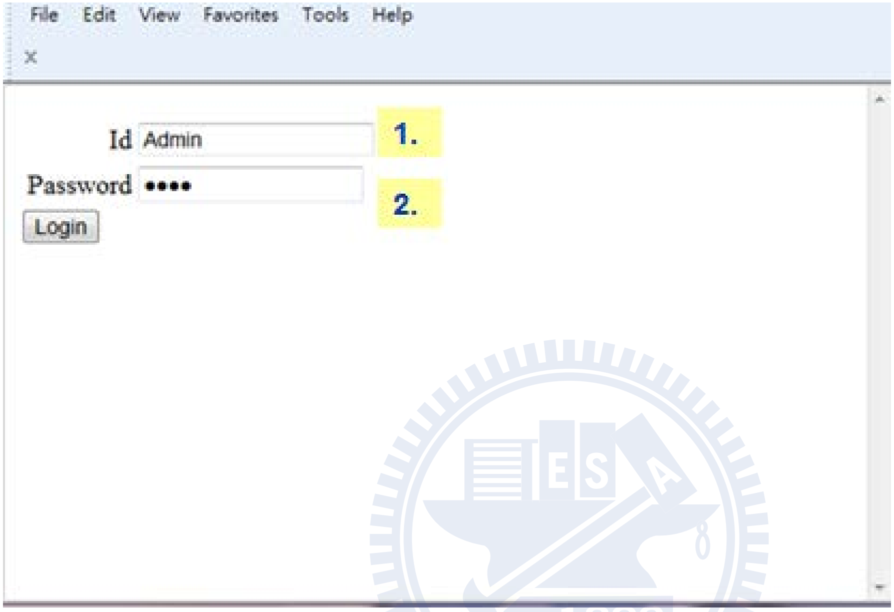
We need to do some test data initialization to make sure our experiments scenarios are executed successfully. Data preparation is including the tables of “USER”, “PATIENT”, and “USER_LOOK_AFTER_PATIENT”. For table “USER”, we will insert one “Admin” role with others as normal user. For these normal users, some of them belong to “Neurology Department”, others are belong to “Orthopedics Department”. For table “PATIENT”, we insert the patient id which exactly matches with our DICOM file test’s patient id. For table “USER_LOOK_AFTER_PATIENT”, we insert a set of data, so that there are users whose department is matches with our DICOM file test’s department and those users has been taken care of the related patient.

4.3 Admin Role Screenshots and Operations

At this section, we will demonstrate how an admin role can performs his actions on the systems with some web browser screenshots.

4.3.1 Admin Login Functionality

1. Input Admin user name id and password
2. Click “Login“ button



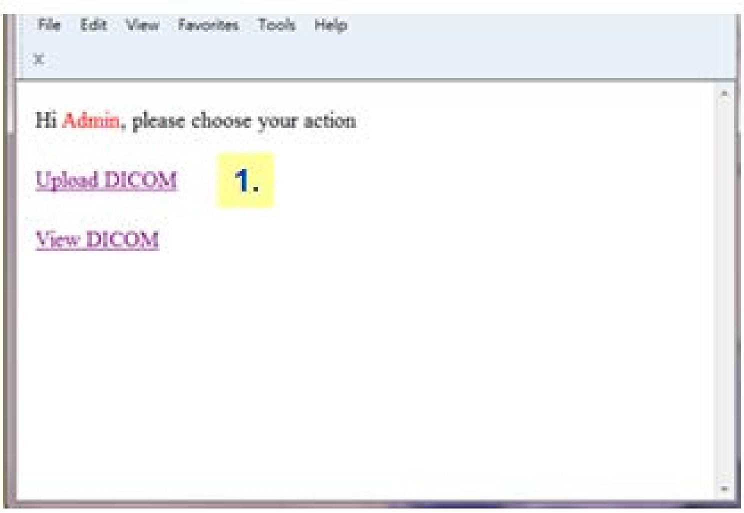
Id Admin

Password ••••

Figure 15. Admin Login

4.3.2 Select Action functionality

1. Select “Upload DICOM” to process



Hi Admin, please choose your action

Upload DICOM

View DICOM

Figure 16. Select Upload DICOM Action

4.3.3 Upload DICOM functionality

1. Browse DICOM file to be uploaded
2. Click “Upload File” to upload the information to web server

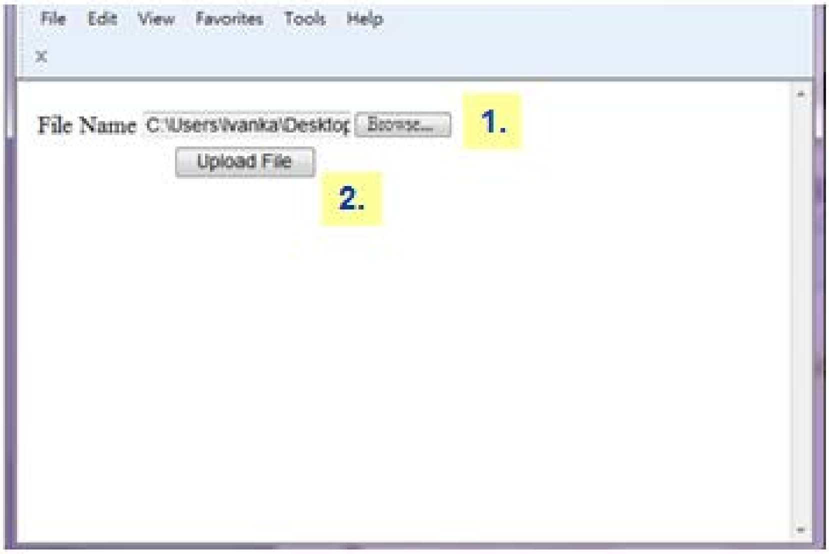
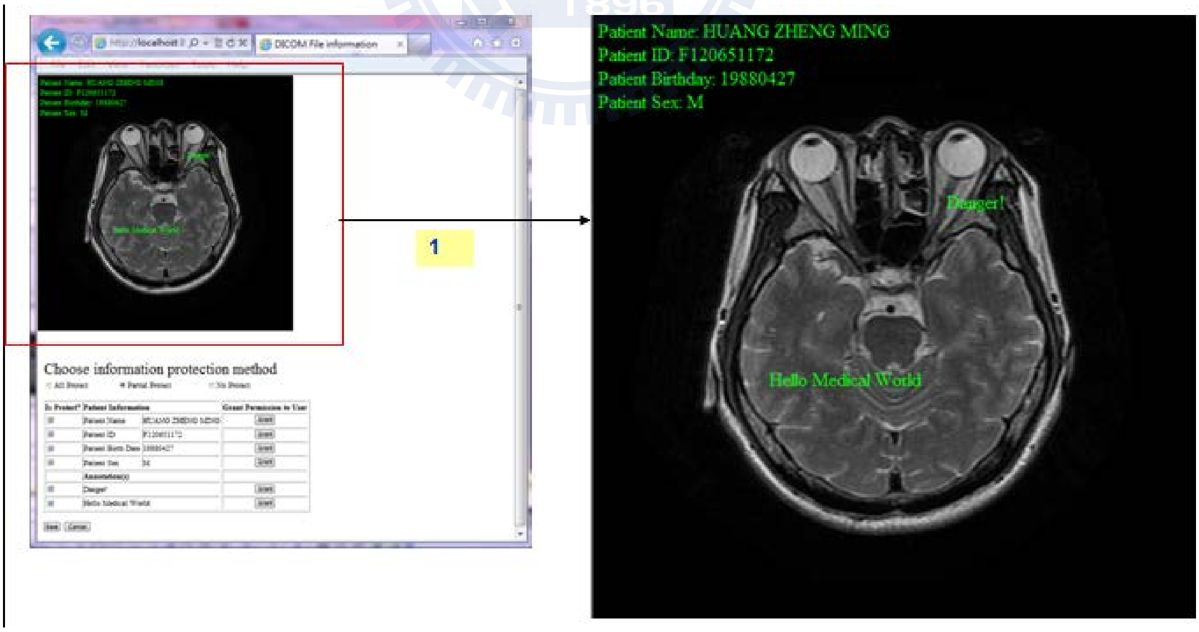


Figure 17. Choose DICOM File to Upload

4.3.4 Show Uploaded DICOM Information

1. System will show DICOM image with patient information and text annotation(s) based on it’ x-axis and y-axis position.



Patient Name: HUANG ZHENG MING
Patient ID: F120651172
Patient Birthday: 19880427
Patient Sex: M

Danger!

Hello Medical World

Choose information protection method

○ All Protect ● Partial Protect ○ No Protect

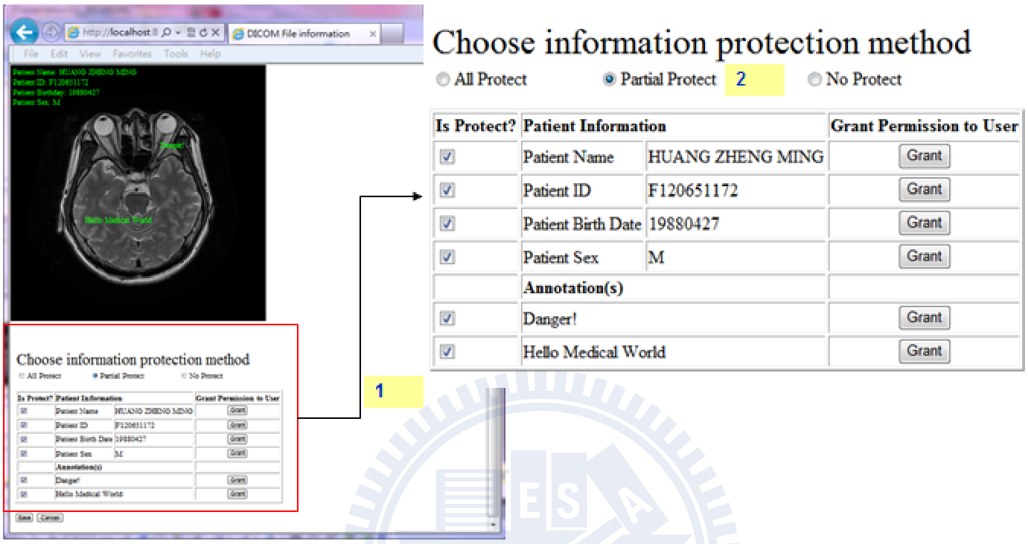
Is Protect?	Patient Information		Grant Permission to User
☒	Patient Name	HUANG ZHENG MING	Grant
☒	Patient ID	F120651172	Grant
☒	Patient Birth Date	19880427	Grant
☒	Patient Sex	M	Grant
	Annotation(s)		
☒	Danger!		Grant
☒	Hello Medical World		Grant

Save Cancel

Figure 18. Show DICOM Information

4.3.5 Choose Information Protection Method - Partial

1. System will list all the DICOM information (patient and annotations), and admin can choose whether to protect the information and grant the view permission to which users.
2. By default behavior, the protection method will be “Partial Protect” with “Is Protect?” flag for all information will be selected. Admin can manually choose whether protect/not protect the information



Choose information protection method

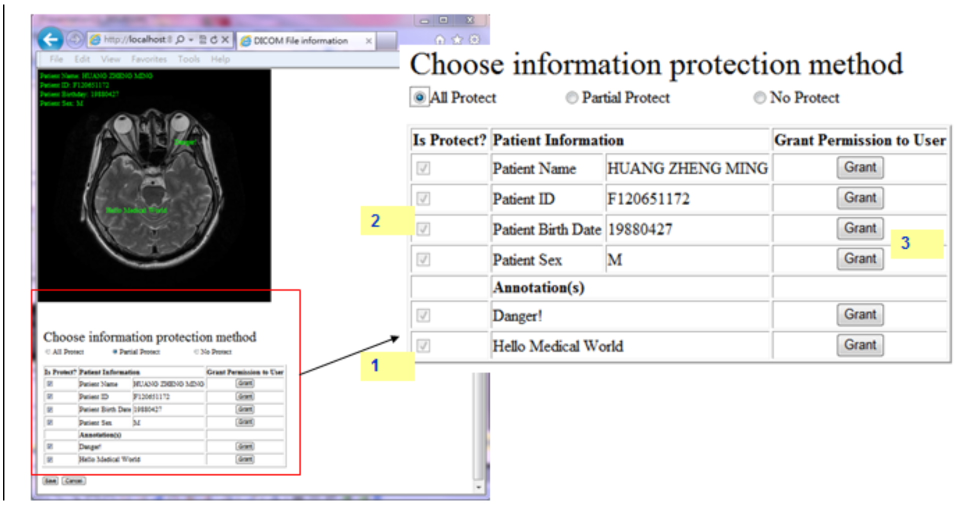
○ All Protect ● Partial Protect ○ No Protect

Is Protect?	Patient Information		Grant Permission to User
☑	Patient Name	HUANG ZHENG MING	Grant
☑	Patient ID	F120651172	Grant
☑	Patient Birth Date	19880427	Grant
☑	Patient Sex	M	Grant
	Annotation(s)		
☑	Danger!		Grant
☑	Hello Medical World		Grant

Figure 19. DICOM Information Partial Protection Method

4.3.6 Choose Information Protection Method – All Protect (Full)

1. When choosing “All Protect” protection method, system will auto select “Is Protect?” flag for all information.
2. Admin can’t manually choose whether protect/not protect the information
3. Admin can grant this protected information view access to other users.



Choose information protection method

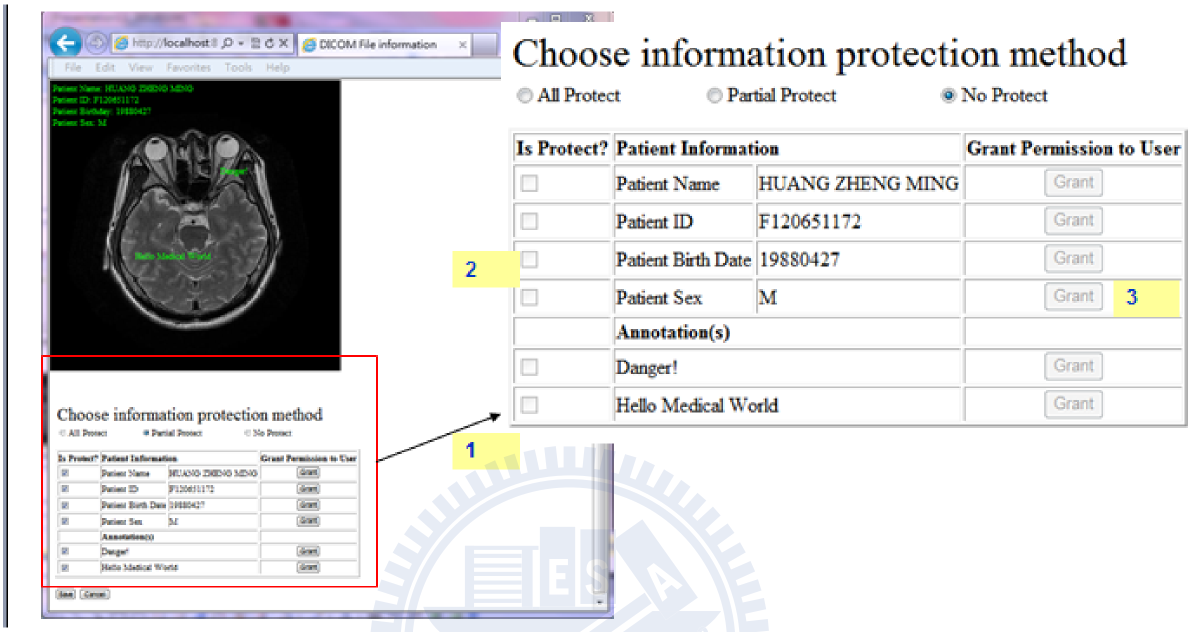
● All Protect ○ Partial Protect ○ No Protect

Is Protect?	Patient Information		Grant Permission to User
☑	Patient Name	HUANG ZHENG MING	Grant
☑	Patient ID	F120651172	Grant
☑	Patient Birth Date	19880427	Grant
☑	Patient Sex	M	Grant
	Annotation(s)		
☑	Danger!		Grant
☑	Hello Medical World		Grant

Figure 20. DICOM Information All Protection Method

4.3.7 Choose Information Protection Method – No Protect

1. When choosing “No Protect” protection method, system will auto clear “Is Protect?” flag for all information.
2. Admin can’t manually choose whether protect/not protect the information.
3. Admin can’t grant this protected information view access to other users, since it is unnecessary.



Choose information protection method

○ All Protect ○ Partial Protect ● No Protect

Is Protect?	Patient Information		Grant Permission to User
☐	Patient Name	HUANG ZHENG MING	Grant
☐	Patient ID	F120651172	Grant
☐	Patient Birth Date	19880427	Grant
☐	Patient Sex	M	Grant
	Annotation(s)		
☐	Danger!		Grant
☐	Hello Medical World		Grant

Figure 21. DICOM Information No Protection Method

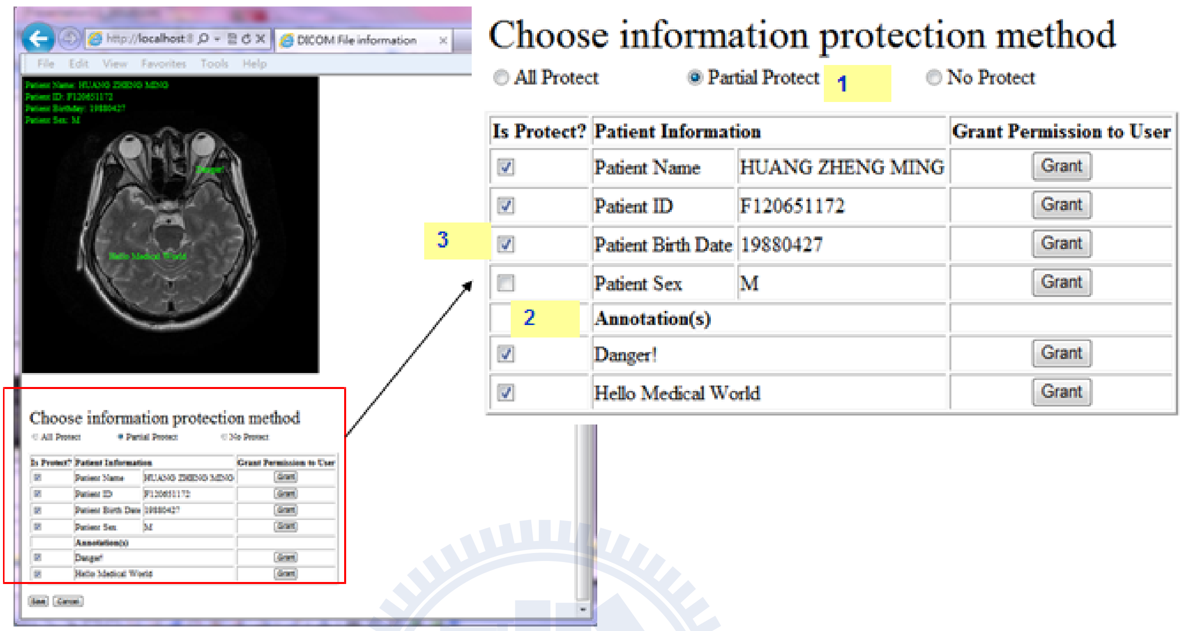
4.3.8 Demo Scenario

We will use below scenario to demo our system mechanism

1. Valid list candidate users: "Bryan", "Cathy", "Dylan", and "Eason" (which have the same department and have been taken care of this patient)
2. "Patient Sex" is considered not so critical and can be exposed to public, so we decide to not protect the related information.
3. "Patient Name" and "Patient ID" is considered very critical, so we decide to protect the related information and grant the permission to one key person (in this case is "Bryan").
4. "Patient Birth Date" and "Text Annotation (s)" is considered critical, so we decide to protect the related information and grant the permission to some authorized persons (in this case is "Bryan", "Cathy", "Dylan", "Eason")

4.3.9 Information Protection Scenario

1. Use “Partial Protect”
2. “Patient Sex” is not protected
3. Other information is protected



Choose information protection method

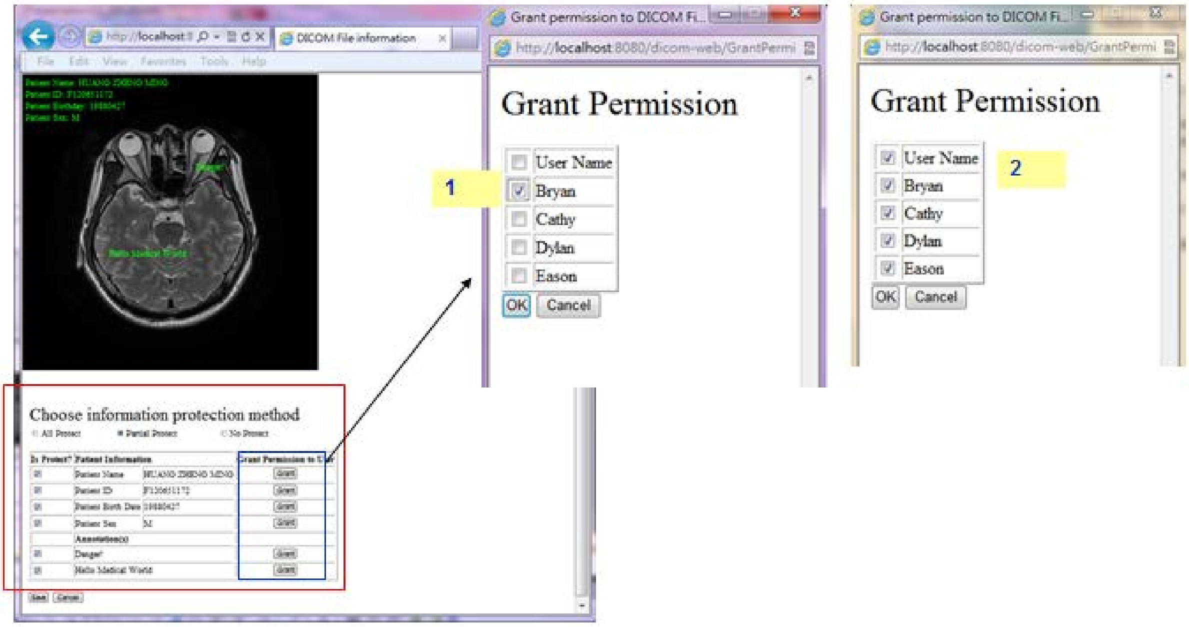
○ All Protect ● Partial Protect ○ No Protect

Is Protect?	Patient Information		Grant Permission to User
☑	Patient Name	HUANG ZHENG MING	Grant
☑	Patient ID	F120651172	Grant
☑	Patient Birth Date	19880427	Grant
□	Patient Sex	M	Grant
	Annotation(s)		
☑	Danger!		Grant
☑	Hello Medical World		Grant

Figure 22. DICOM Information Protection Scenario

4.3.10 Grant User Permission Scenario

1. “Patient Name” and “Patient ID” is granted to “Bryan”
2. "Patient Birth Date" and "Text Annotation (s)" is granted to: “Bryan”, “Cathy”, “Dylan”, and “Eason”.



Grant Permission

□ User Name
☑ Bryan
□ Cathy
□ Dylan
□ Eason

OK Cancel

Grant Permission

☑ User Name
☑ Bryan
☑ Cathy
☑ Dylan
☑ Eason

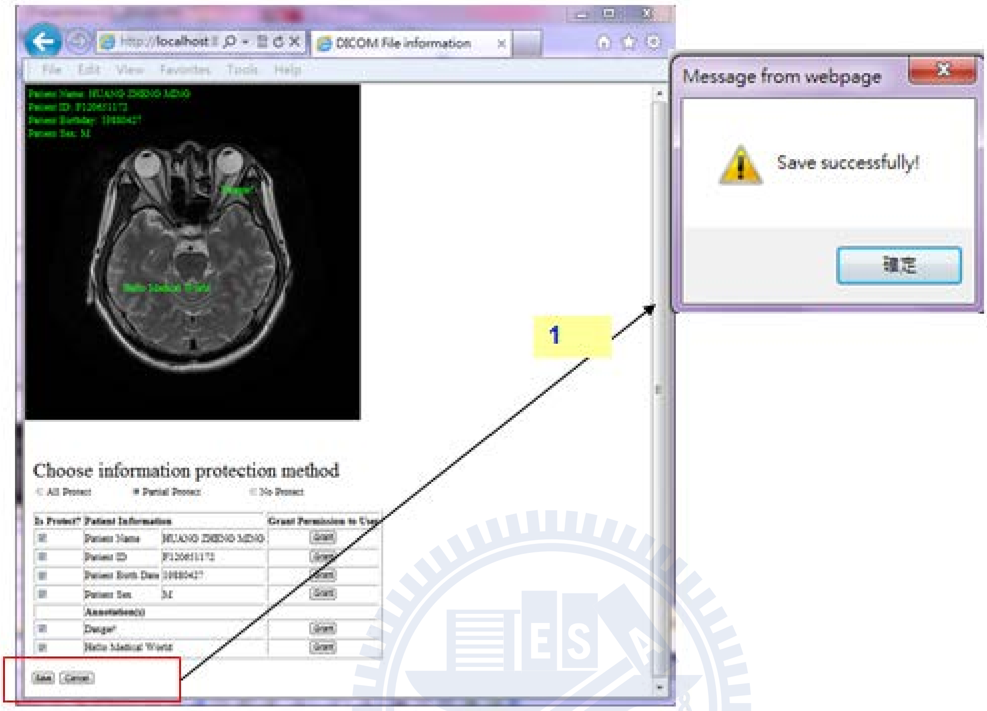
OK Cancel

Grant permission to DICOM Fi...
http://localhost:8080/dicom-web/GrantPermi
http://localhost
DICOM File information
File Edit View Favorites Tools Help
Patient Name: HUANG ZHENG MING
Patient ID: F120651172
Patient Birthday: 19880427
Patient Sex: M
Choose information protection method
Save
Cancel
1
2

Figure 23. Grant User Permission for DICOM Information

4.3.11 Save to Database

1. After all information protection and permission granting has been done, user can click “Save”. System will save all the information to server’s database, and show “Save successfully!” message to user.



Patient Name: HUANG ZHENG MING
Patient ID: F120651172
Patient Birthday: 19880427
Patient Sex: M

Choose information protection method

○ All Protect ● Partial Protect ○ No Protect

Is Protect?	Patient Information		Grant Permission to User
☑	Patient Name	HUANG ZHENG MING	Grant
☑	Patient ID	F120651172	Grant
☑	Patient Birth Date	19880427	Grant
☑	Patient Sex	M	Grant
	Annotation(s)		
☑	Danger!		Grant
☑	Hello Medical World		Grant

Save Cancel

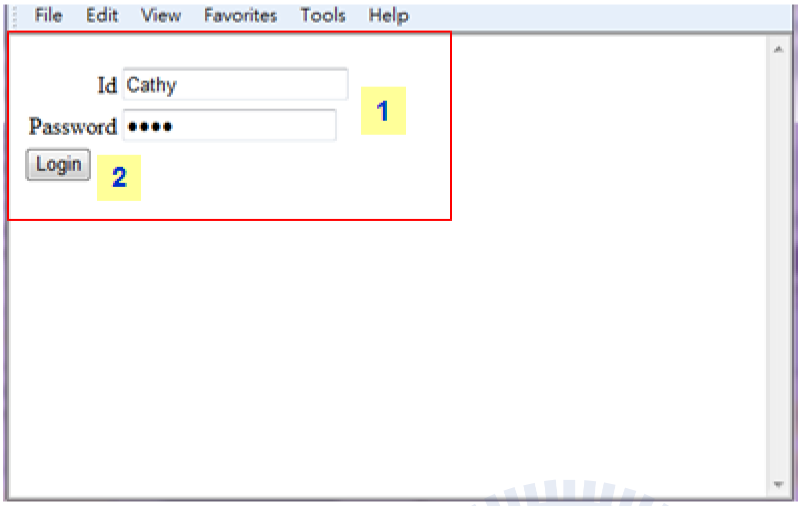
Save successfully!

Figure 24. Save DICOM Information to Database

4.4 User Role Screenshots and Operations

4.4.1 User Login Functionality

1. Input user name id and password (For this scenario, we choose “”Cathy)
2. Click “Login”button



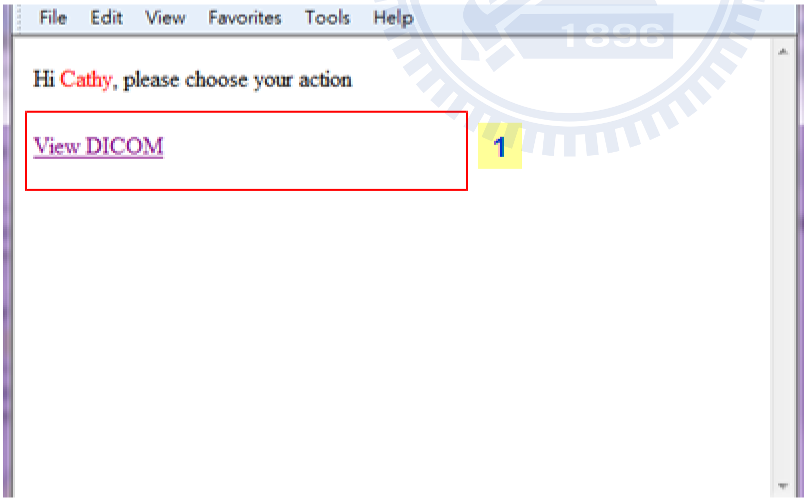
Id Cathy

Password ••••

Figure 25. User Login

4.4.2 Select Action Functionality

1. Select “View DICOM” to process

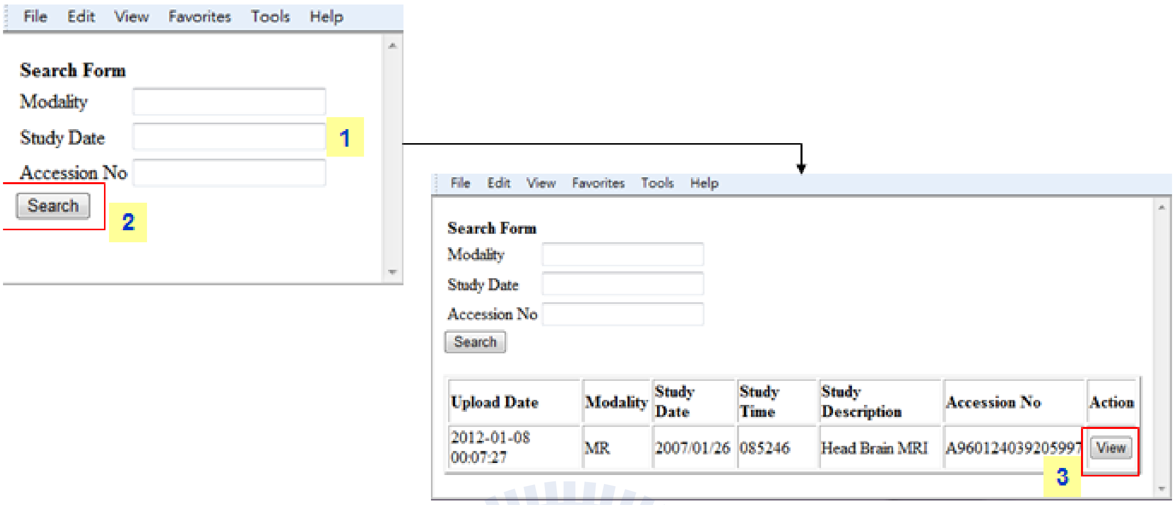


Hi Cathy, please choose your action

Figure 26. Select View DICOM Action

4.4.3 Select DICOM Functionality

1. User can input the related search criteria (optional)
2. Click “Search”, and based on the search criteria, system will show the result list on the screen
3. Click “View” to see the detail DICOM information target



Search Form

Modality

Study Date

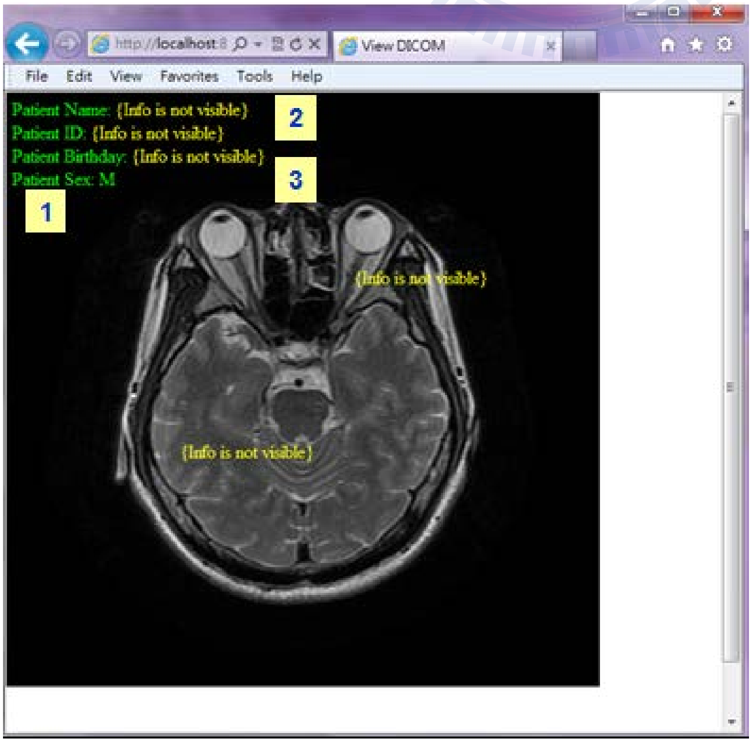
Accession No

Upload Date	Modality	Study Date	Study Time	Study Description	Accession No	Action
2012-01-08 00:07:27	MR	2007/01/26	085246	Head Brain MRI	A960124039205997	View

Figure 27. Select DICOM Target to View

4.4.4 View DICOM Functionality

1. “Patient Sex” is not protected
2. “Patient Name” and “Patient ID” only granted to “Bryan”
3. User can only view “Patient Birth Date” and “Text Annotation (s)”



Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: {Info is not visible}
Patient Sex: M

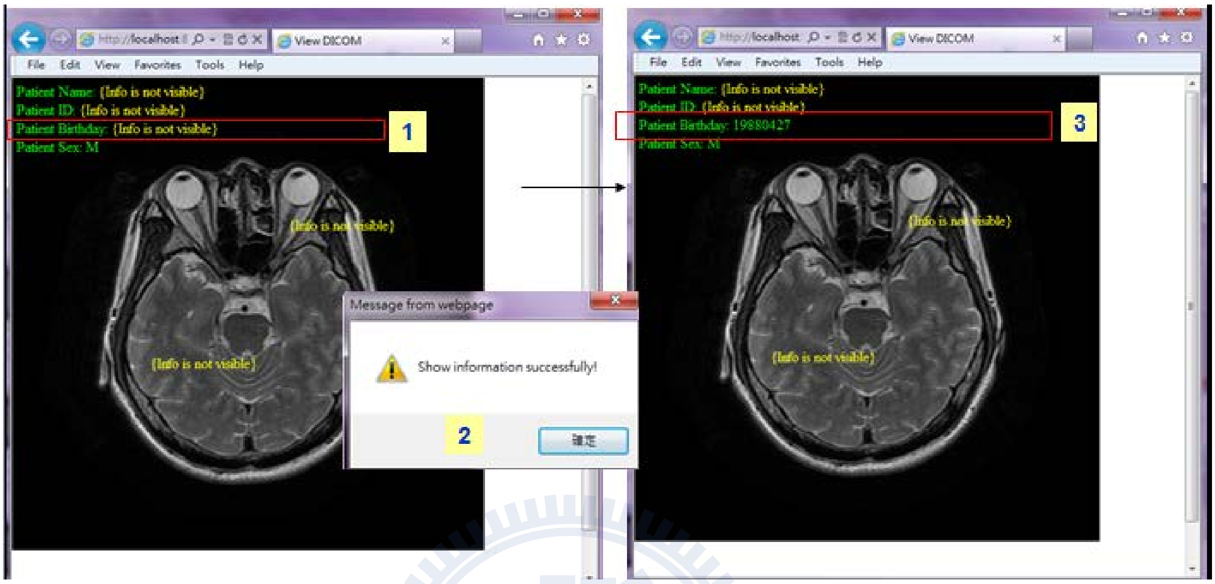
{Info is not visible}

{Info is not visible}

Figure 28. View DICOM

4.4.4.1 View Patient Birthday

1. Try to view the “Patient Birthday” by clicking the related information
2. System show message: “Show information successfully!” since the related user have permission to view this information
3. “Patient Birthday” will be shown on the screen



Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: {Info is not visible}
Patient Sex: M
{Info is not visible}
{Info is not visible}

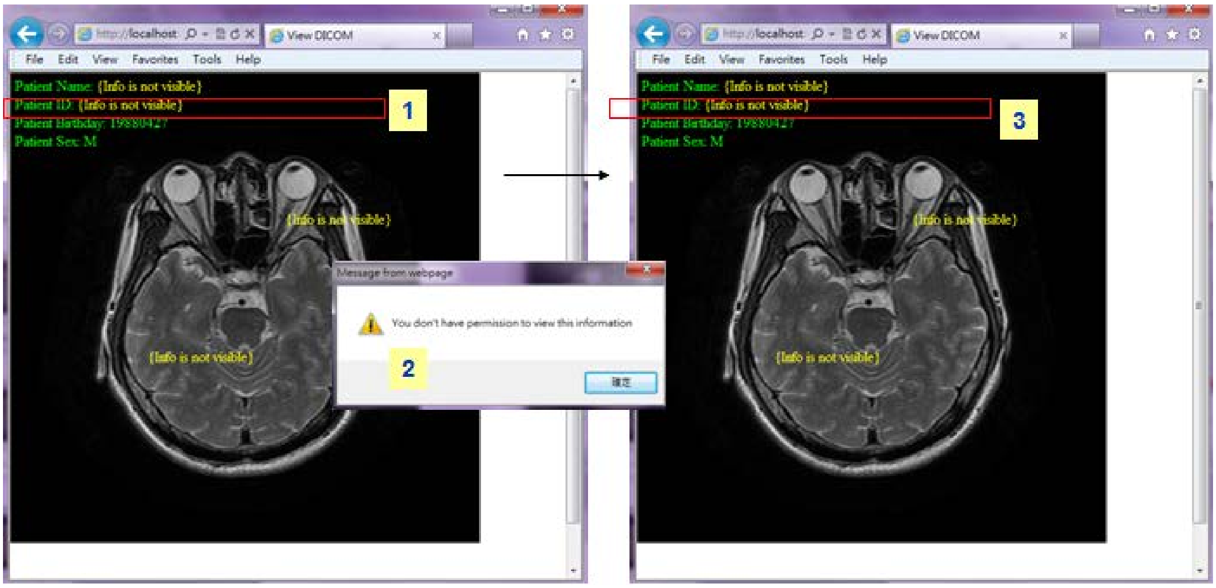
Message from webpage
Show information successfully!

Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M
{Info is not visible}
{Info is not visible}

Figure 29. View Patient Birthday Action

4.4.4.2 View Patient ID

1. Try to view the “Patient ID” by clicking the related information
2. System show message: “You don’t have permission to view this information” since the related user don’t have the permission to view this information
3. “Patient ID” will not shown on the screen



Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M
{Info is not visible}
{Info is not visible}

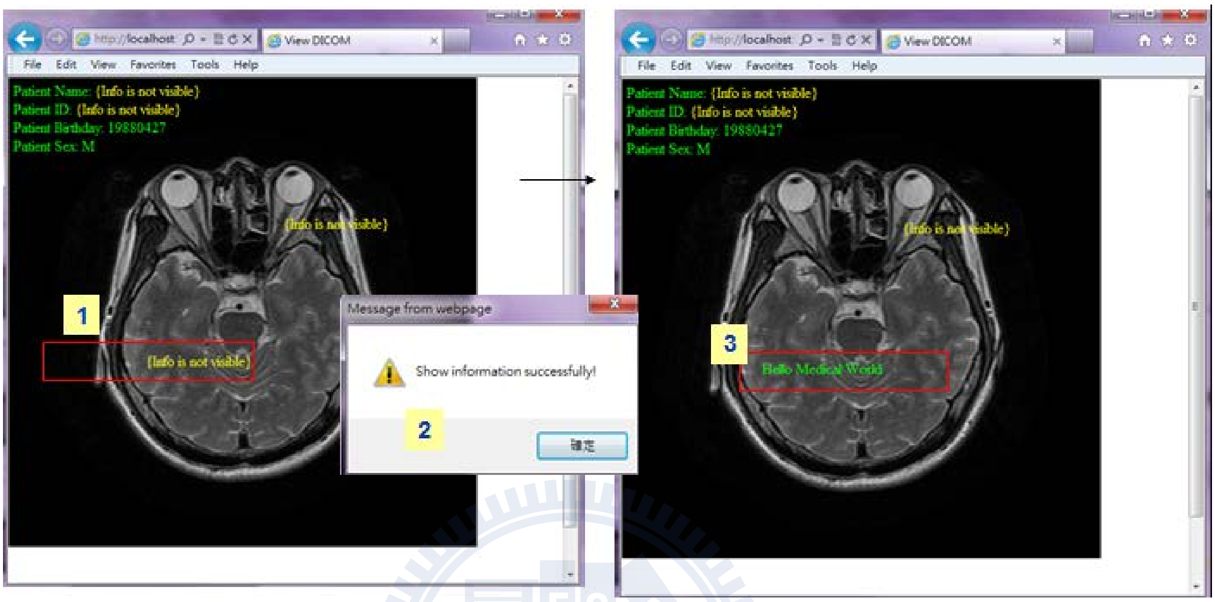
Message from webpage
You don't have permission to view this information

Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M
{Info is not visible}
{Info is not visible}

Figure 30. View Patient ID Action

4.4.4.3 View Text Annotation(s)

1. Try to view the text annotation by clicking the related information
2. System show message: “Show information successfully!” since the related user have permission to view this information
3. The related text annotation will be shown on the screen

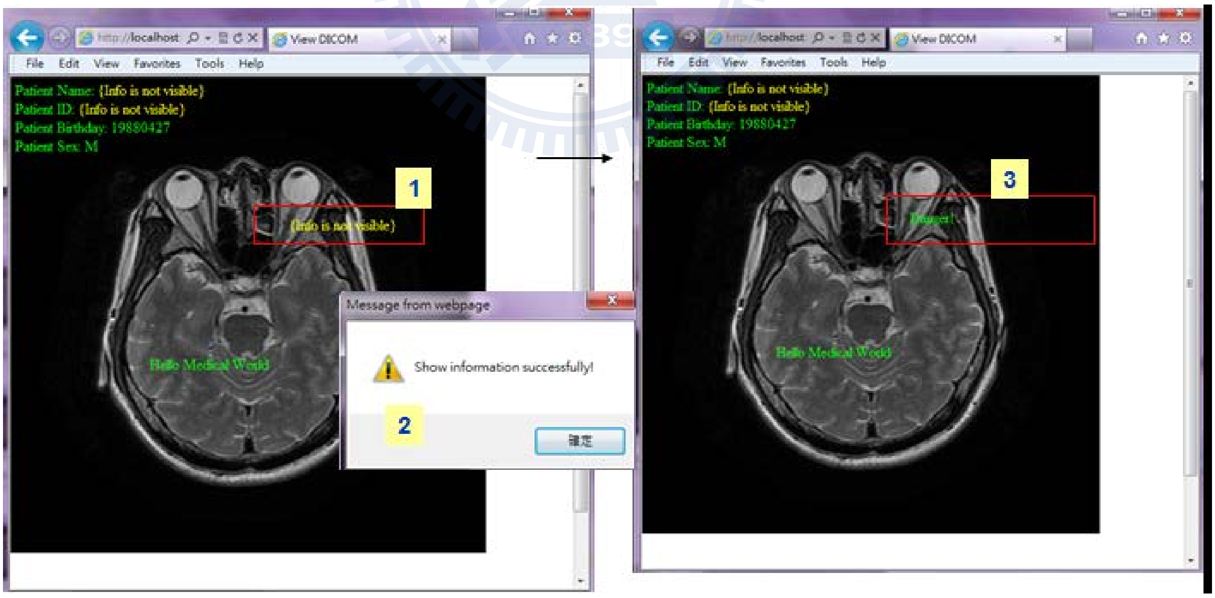


Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M

Message from webpage

Show information successfully!

Figure 31. View Text Annotation (1)



Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M

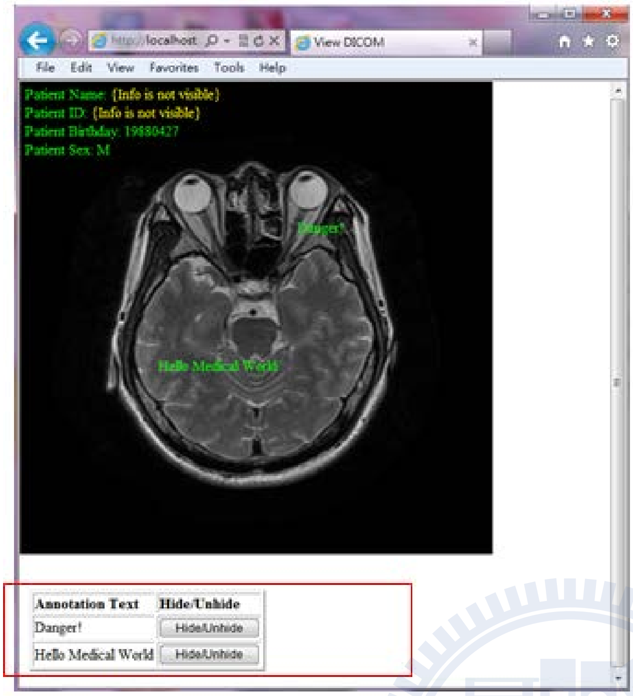
Message from webpage

Show information successfully!

Figure 32. View Text Annotation (2)

4.4.4.4 Hide / Unhide Text Annotation(s)

Considering user want to see the DICOM image without annotation text (s) intervention, system enable user to hide/unhide the information from the screen.

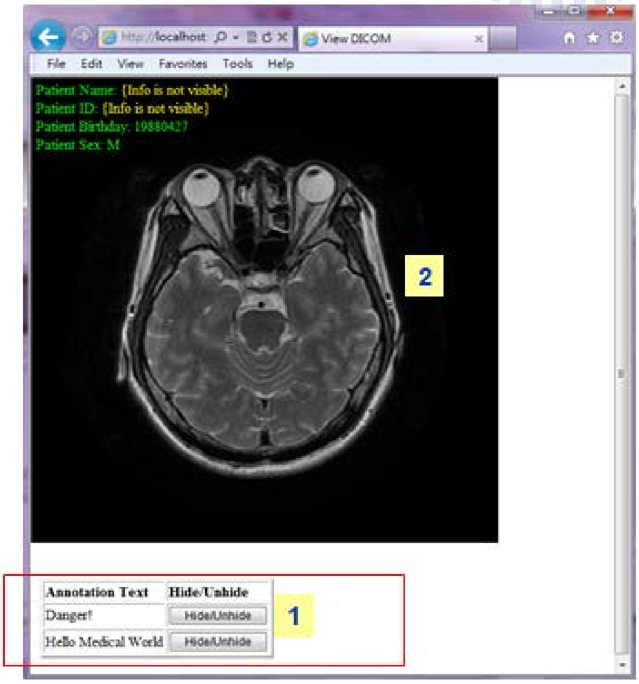


Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M

Annotation Text	Hide/Unhide
Danger!	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 33. Hide or Unhide Functionality for Text Annotation on DICOM Information

1. Hide text annotations information by clicking the button “Hide / Unhide” button
2. System will hide the information from the screen, so that user can see the DICOM image without text intervention clearly

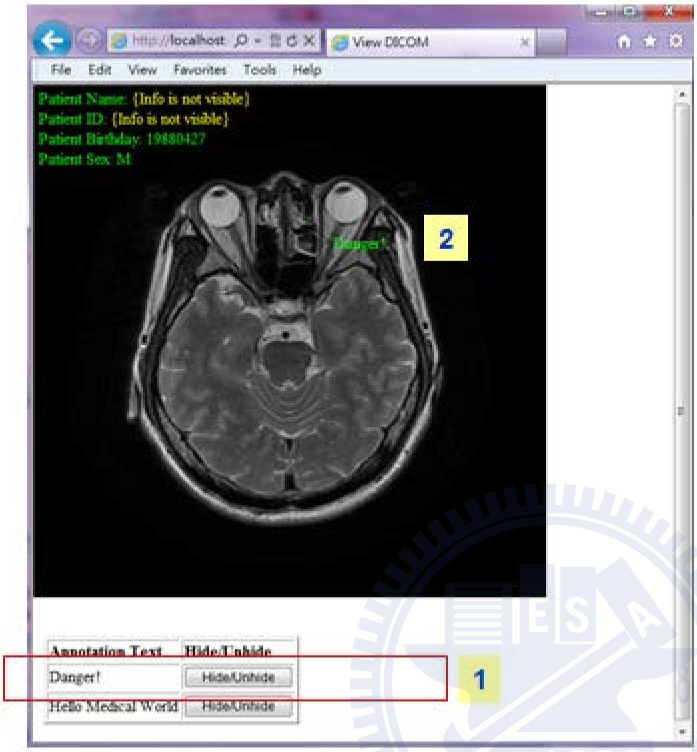


Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M

Annotation Text	Hide/Unhide
Danger!	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 34. Hide Text Annotation on DICOM Information

1. Unhide one of the text annotation by clicking the related information’s “Hide/Unhide” button
2. System will unhide the information from the screen, so that user can see the information on DICOM image



Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: 19880427
Patient Sex: M

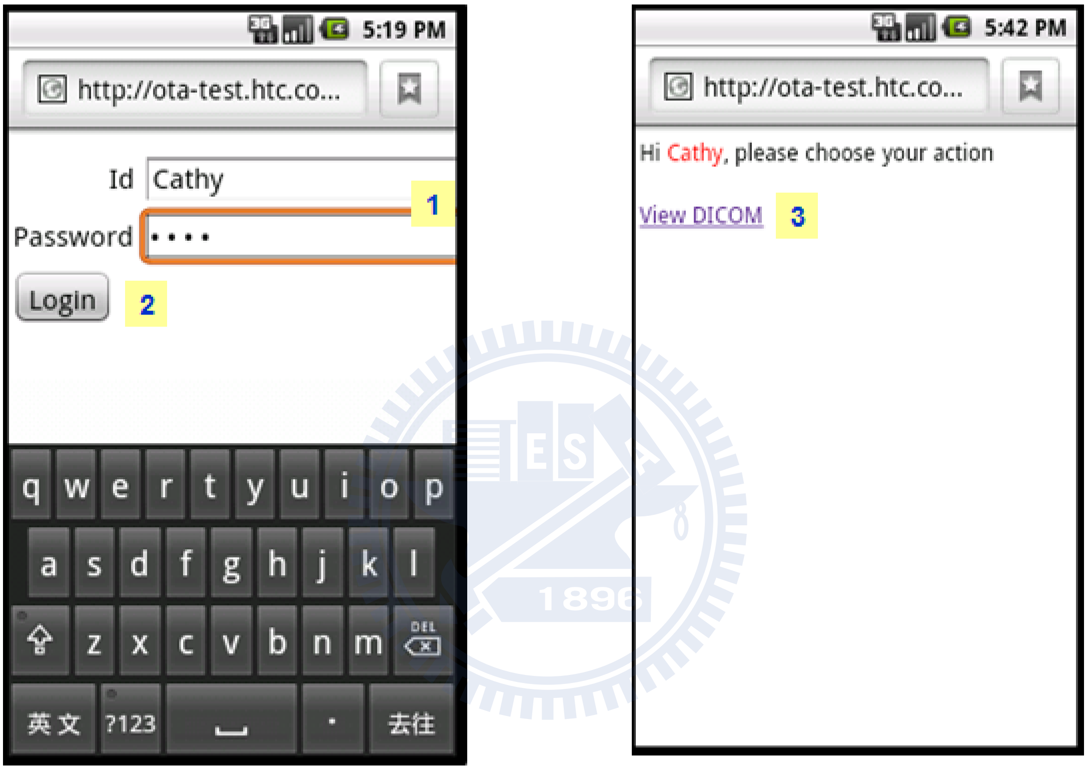
Annotation Text	Hide/Unhide
Danger!	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 35. Unhide Text Annotation on DICOM Information

4.5 Smart phone devices

We using an android smart phone based to do “View DICOM information” experiments process. Below are the screenshot from android emulator

1. Input user name id and password
2. Click “Login” button
3. Select “View DICOM” to process



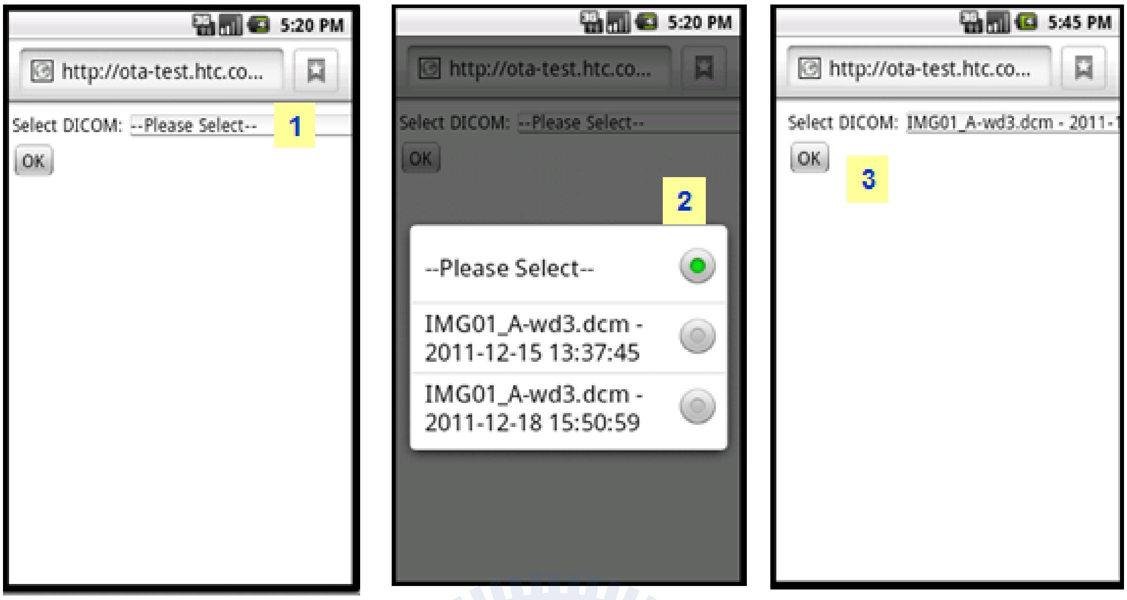
Id Cathy

Password ••••

Hi Cathy, please choose your action

Figure 36. Smartphone Experiment – Login and View Action

1. Click the combo box to select DICOM target
2. Select DICOM target
3. Click "ÖK" button to process


http://ota-test.htc.co...

Select DICOM: --Please Select--

--Please Select--

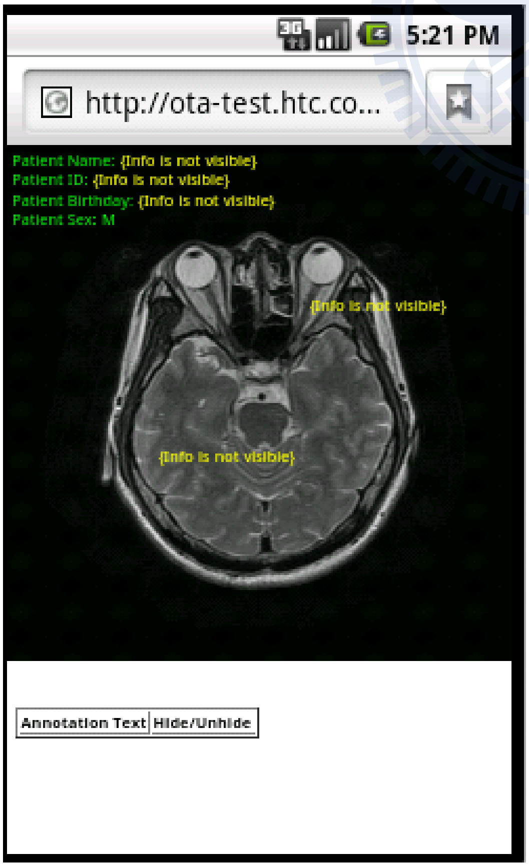
IMG01_A-wd3.dcm - 2011-12-15 13:37:45

IMG01_A-wd3.dcm - 2011-12-18 15:50:59

Select DICOM: IMG01_A-wd3.dcm - 2011-1

Figure 37. Smartphone Experiment – Select View DICOM Target

View DICOM


http://ota-test.htc.co...

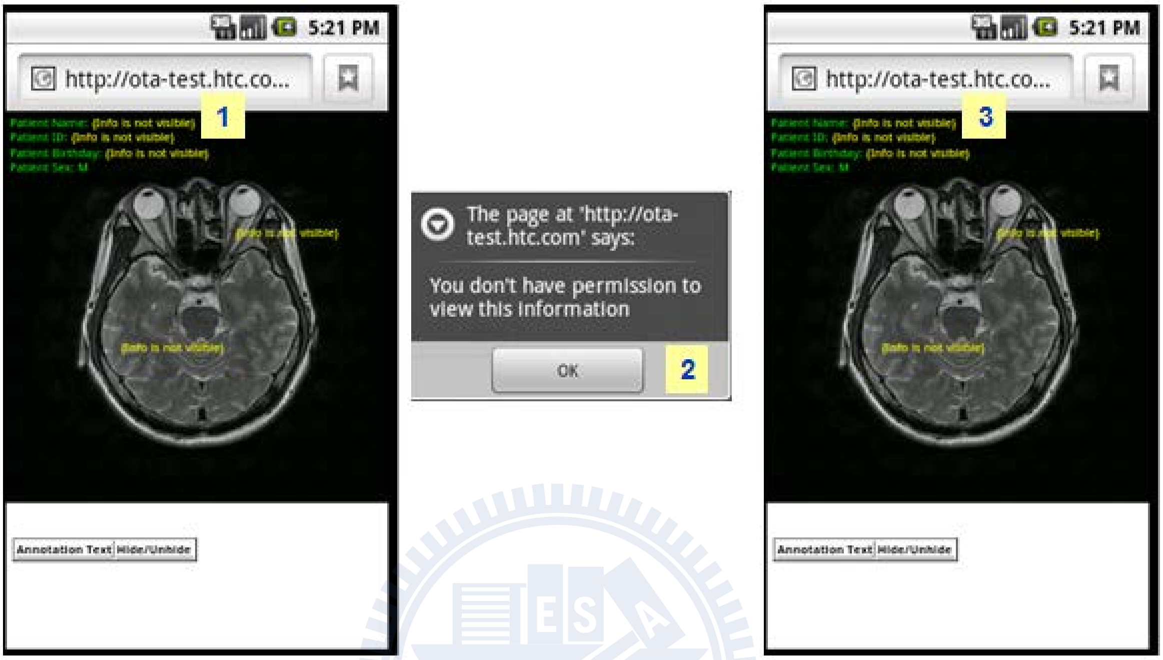
Patient Name: {Info is not visible}
Patient ID: {Info is not visible}
Patient Birthday: {Info is not visible}
Patient Sex: M

{Info is not visible}

{Info is not visible}

Figure 38. Smartphone Experiment – View DICOM

1. Try to view the “Patient ID” by clicking the related information
2. System show message: “You don’t have permission to view this information” since the related user don’t have the permission to view this information
3. “Patient ID” will not shown on the screen



Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M

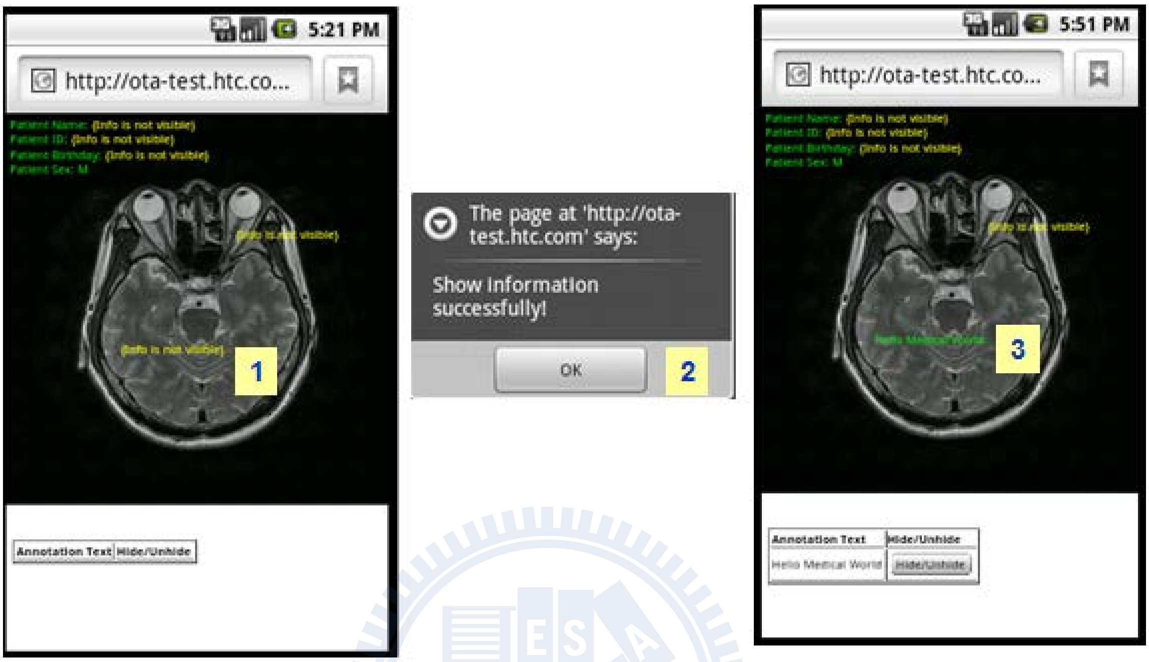
The page at 'http://ota-test.htc.com' says:

You don't have permission to view this information

Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M

Figure 39. Smartphone Experiment – View Patient ID

1. Try to view the text annotation by clicking the related information
2. System show message: “Show information successfully!” since the related user have permission to view this information
3. The related text annotation will be shown on the screen


5:21 PM
http://ota-test.htc.co...
Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M
(Info is not visible)
(Info is not visible)
1
Annotation Text
Hide/Unhide
2
5:51 PM
http://ota-test.htc.co...
Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M
(Info is not visible)
Hello Medical World
3
Hide/Unhide

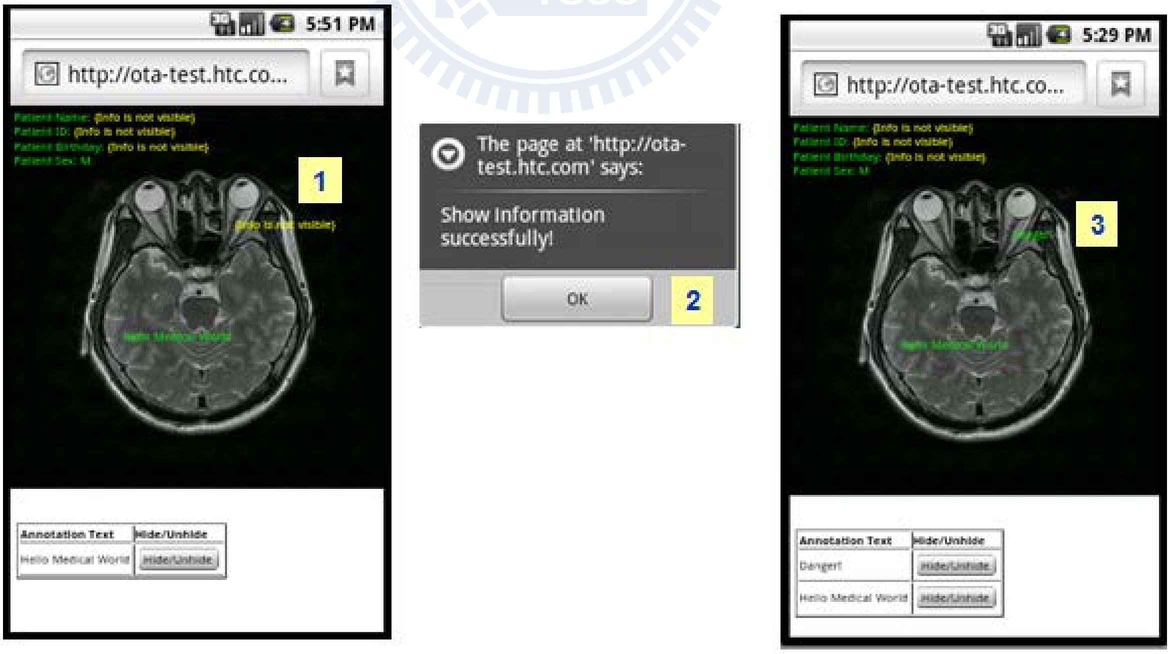
The page at 'http://ota-test.htc.com' says:

Show Information successfully!

OK

Annotation Text	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 40. Smartphone Experiment – View Text Annotation (1)


5:51 PM
http://ota-test.htc.co...
Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M
1
(Info is not visible)
Hello Medical World
2
5:29 PM
http://ota-test.htc.co...
Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M
3
Danger!
Hello Medical World

Annotation Text	Hide/Unhide
Hello Medical World	Hide/Unhide

The page at 'http://ota-test.htc.com' says:

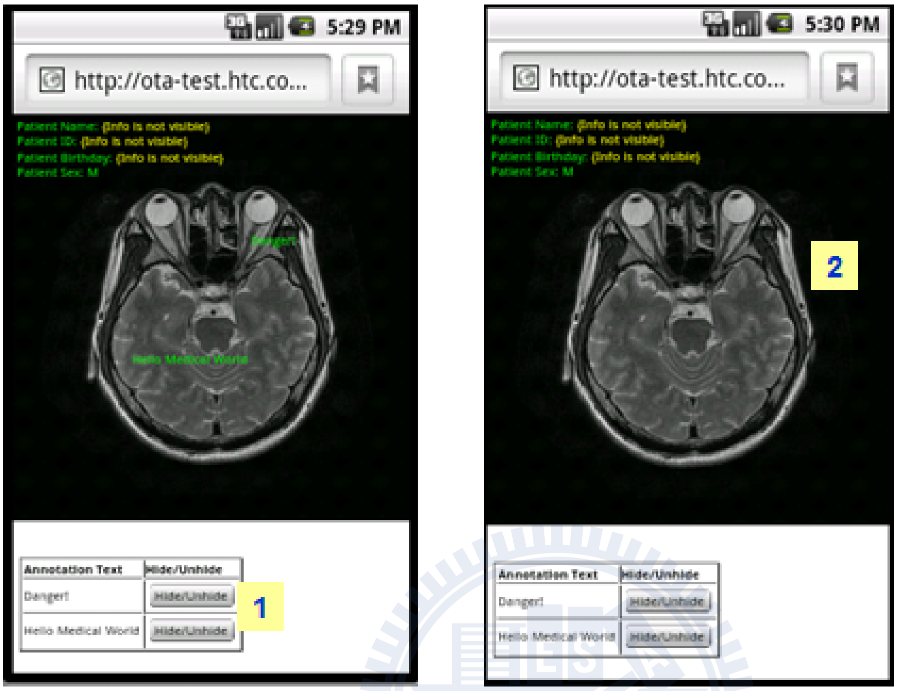
Show Information successfully!

OK

Annotation Text	Hide/Unhide
Danger!	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 41. Smartphone Experiment – View Text Annotation (2)

1. Hide text annotations information by clicking the button “Hide / Unhide” button
2. System will hide the information from the screen, so that user can see the DICOM image without text intervention clearly



Patient Name: (Info is not visible)
Patient ID: (Info is not visible)
Patient Birthday: (Info is not visible)
Patient Sex: M

Annotation Text	Hide/Unhide
Danger!	Hide/Unhide
Hello Medical World	Hide/Unhide

Figure 42. Smartphone Experiment - Hide and Unhide Functionality

5 Conclusions and Future Work

5.1 Conclusions

This thesis proposed solution to make DICOM information available in cloud environment

- Convenience, since information can be accessed anytime anywhere as long as user got internet access and device built in web browser

- For partial data protection and sharing mechanism:
  - Sharing data to suitable group of peoples can be achieved
  - Enable user to show suitable information based on the situation (ex. seminar)

5.2 Future Work

On the future, we can do some functionality extension to make the system a better application with below direction:

- Integration with DICOM multimedia annotator
  - Online annotate DICOM information
  - Support text, image, audio, and video annotation

- Integration with hospital system
  - DICOM data input is from PACS
  - Radiology machine output DICOM, and automatically upload it to web browser

- Web server security mechanism
  - HTTPS implementation on user authentication and view DICOM pages.

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