# Picture Archiving and Communication System Design and Implementation

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## Abstract

PACS (Picture archiving and communication system) has been vastly introduced as a reliable alternative to the conventional film- and paper-based healthcare system. It has been in existence for several years and has become an integral part of the infrastructure of radiology and imaging departments across the world. Services provided by PACS establish a platform for the diagnosis of different diseases. PACS serves as a more convenient means of teaching students of radiology, it also reduces transmissions time requirement for referral cases and access time to images and radiological report over the network and improves on the time of patient consultation. In this paper we discuss the construction of (PACS) for hospitals that provides electronic storage, retrieval, manipulation, distribution and presentation of medical images using a popular format named DICOM. This research work implements a PACS model with the incorporation of new features. Its objectives were achieved: converting non DICOM images to DICOM standard and reduced transmission time and storage space requirements of radiological images. The model is implemented using the visual studios.

**Keywords:** PACS, imaging modality, medical images, DICOM, image conversion

## 1. Introduction

Several hospitals around the world have now realized the great possibilities of using digital images mainly because of the limitless potentials in terms of management, transmission, handling and replication (Alberto Pastrana Palma, 2010). Picture Archiving and Communication System (PACS) is a medical system (consisting of necessary hardware and software) and represents essential component of Hospital Information System (HIS) (Yue Zhao, 2010). It provides economical storage and convenient access to images from multiple modalities (source machine types) and breaks down the physical and time hindrance associated with traditional film-based image retrieval, distribution, and display. Web-based applications as opposed to pre-installed software offer a multiplatform technology that allows physicians to access such systems. Over the past decade, PACS have welcomed web-based technologies and opened

Their horizons to a new digital age of Teleradiology (Alberto Pastrana Palma, 2010). These systems utilize the Internet as their means of communication, usually via VPN or SSL (Alamu F. O., 2011). Definitely, one of the main advantages of using PACS is to offer radiologists around the world a platform to detect important diseases such as pancreatic cancer where appropriate diagnostic is essential to save a human live. For example, examinations taken in Baghdad could be accessed by a radiologist in New Delhi once they are acquired in order to pursue consultations to quickly and actively take actions, hence improving the chances of a successful patient recovery (Alberto Pastrana Palma, 2010). PACS also support dentists to be able to perform their roles with modern technology to provide advanced twenty-first century healthcare service (Nakintorn Patanachai, 2008). In PACS, medical images are stored in an independent format. The most common format for image storage is DICOM which is brought up by ACR and NEMA in the early 1990's (Yue Zhao, 2010). DICOM stands for Digital Imaging and Communications in Medicine and represents years of effort to create the most universal and fundamental standard in digital medical imaging. As such, it provides all the necessary tools for diagnostically precise representation and processing of medical imaging data. Moreover, contrary to popular belief, DICOM is not just an image or file format. It is an all-encompassing data transfer, storage and display protocol built and designed to cover all functional aspects of contemporary medicine (which is why many view DICOM as a set of standards, rather than a single standard). Without a doubt, DICOM truly governs practical digital medicine (Oleg S. Pianykh, 2012). However, because of the outdated imaging modalities, hospitals are still using the non-DICOM image which brings difficulties for diagnosing. Therefore, how to convert non-DICOM images to DICOM images becomes a challenging problem in the medical software field (Yue Zhao, 2010). Modern PACS comprise:

1. Modalities: Digital image acquisition devices such as computed tomography (CT) or ultrasound.
2. Digital image archives: Where the acquired images are stored.

3.   Workstations: Where radiologists view ("read") the images (Oleg S. Pianykh, 2012). Due to the fact that many imaging equipment are not supporting industrial standards, like the DICOM standard, acquisition computers (also called acquisition gateways) are needed to enable the digital exchange of the images. Therefore a computer is placed between the modalities and the PACS network. The computer receives the picture from the imaging modality through its specified interface, preprocessing it and converting it to a standard, which is supported by the PACS (i.e. the DICOM standard) (Maximilian

Hecht, 2008). Filmless image management systems will become common in all hospitals in the near feature. All staff in each hospital should examine the merits and demerits of this system. PACS simplifies access to specialists around the world without their physical presence and removes access barriers and geographical constraints (Alamu F. O., 2011).

## 2.   PACS Components

In this section we present the different components comprising PACS that we use to implement our project:
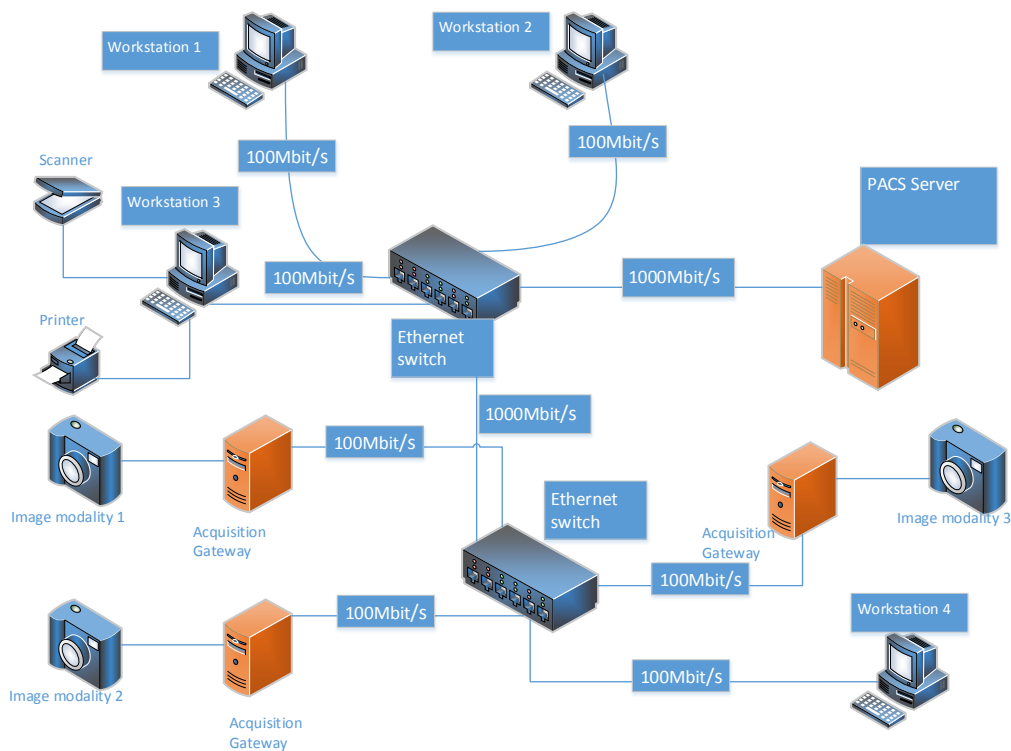


**Figure 1:** PACS components

### a.  Acquisition Gateway:

There are different types of imaging modalities exist like X-ray, Computed Tomography (CT) scans, MRI, etc. The images are transmitted from the modalities using a specified format. A DICOM is the most frequently used standard. Due to the fact that many Imaging modalities are not supporting the DICOM standard and for backwards compatibility necessity, acquisition computers (acquisition gateways) are needed to enable digital transformation of the images.

Therefore, a computer is placed between the modality and the PACS network. The computer receives the image from the imaging modality in DICOM, jpg or other formats, process it and convert it to DICOM standard (in case it is in a format other than DICOM) which is the standard supported by PACS for the purpose of

exchanging images between the modalities and the acquisition gateways.

### b. PACS server:

Typically a PACS network has a central server which stores a database containing the received images (Alamu F. O., 2011). This server ensures that all images are grouped into the correct examination, chronologically ordered, correctly orientated and labeled, and can be easily retrieved using a variety of criteria (patient name, date of examination, referring physician, etc.). All the imaging studies of a patient become available on PACS which encourages review of examinations with preceding studies. Our PACS server consists of three components as follow:

- The first part is the archiving and management which is used to archive the DICOM files received from the acquisition

gateways, back up the database, add Information Technicians, doctors and patients to the system in addition to other managerial processes. We used C#.net to implement this part.

• The second part is the web server which is used as an interface between the workstation

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website and the database located in this server. We use the IIS (Internet Information Services) server.

• And the last part is the SQL server.
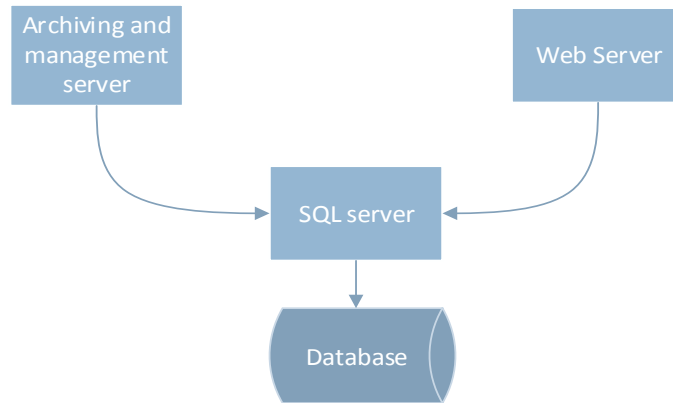
The first and second parts are used as interfaces for the SQL database server



**Figure 2:** PACS Server parts

### c. Workstations:

A workstation is a computer used to browse the PACS website. The physicians and/or doctors use the workstations instead of the former illumination boxes. The workstation should have a web browser installed.

### d. Network

All the previous components have to be supported by a robust and secure network, which is the backbone of the PACS. The appropriate configuration of routers, switches and firewalls is critical to the implementation of a secure and efficient PACS (Arjun Kalyanpur, 2010). It is recommended that imaging modalities and their

acquisition gateways are grouped in local area networks (LAN); many of such networks are connected by a wide area network (WAN), provided by a regional Internet service provider (ISP). In the future, increasing WAN speed will allow hospitals to work together over larger distances sharing one PACS system. For keeping the network simple and scalable for Microsoft Windows based computers, the TCP/IP protocol is recommendable. As technologies for the local area network, the Ethernet protocol following the IEEE 802.x standard can be used. Ethernet provides high network speed with up to 10 Gigabit/s (Maximilian Hecht, 2008).

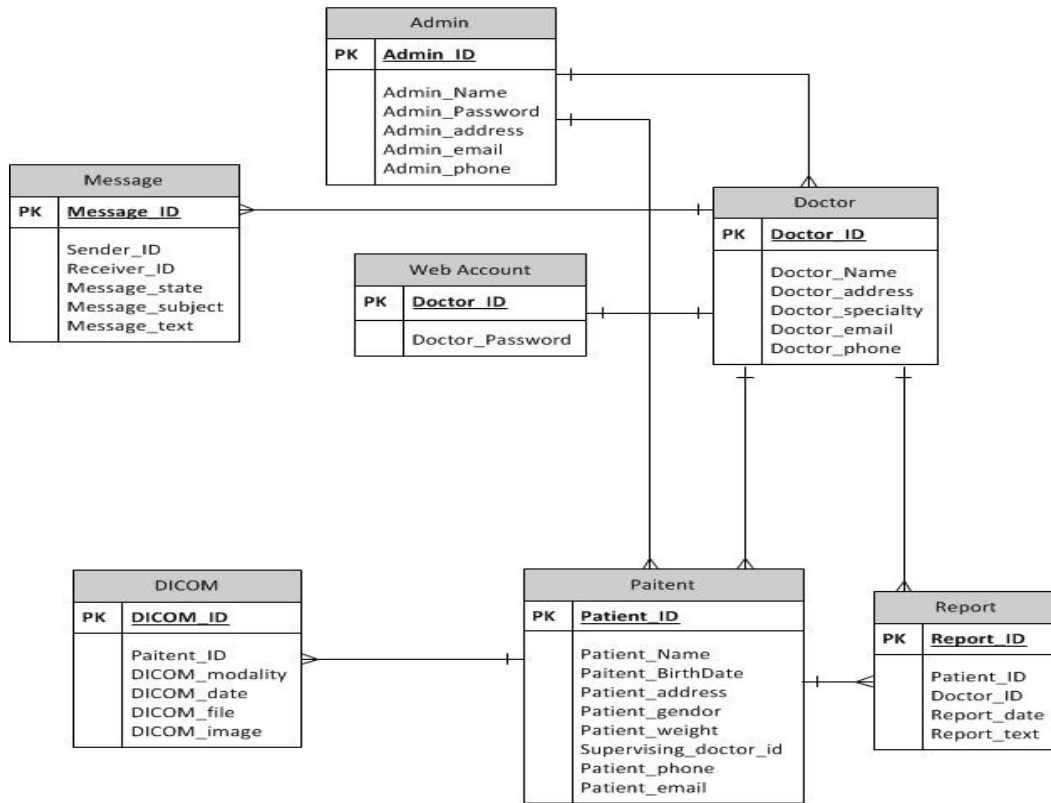### 3.  Database design (Entity Relationship Diagram):



**Figure 3:** ER Diagram

### 4.  Development Platform

The choices in terms of development platform should realize the distributed components under client-server architecture. On one side, one must consider all image and data services that should be implemented in order to allow the web server to send and receive images. On the other side, the client applications must provide tools for visualizing and manipulating such images. To meet such requirements, we developed three software components, the first one run on the acquisition gateways and it is programmed using C#.net. Libraries such as DICOM objects 2.0 from Medical Connections enable a variety of tools to dynamiclly interact with images over a .NET platform. The second component is the server side with two ends; the front end is C#.net and for maintaining the data in the database, Microsoft SQL Server 2010 is used as the back end. The third component is the PACS website which is implemented using ASP.net.

### 4.1 Acquisition Gateway Design (GUI and Functionality):

In the main form of the acquisition gateway application we have the following choices as shown in (Fig 8).
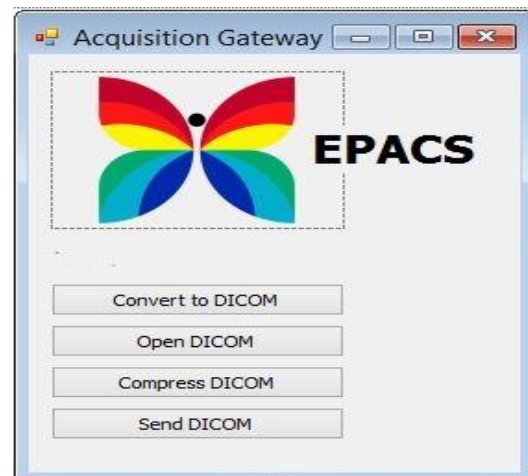


**Figure 4:** Acquisition Gateway Main form

### 4.1.1 Convert to DICOM

Modern radiology modalities, feed patient images directly to the PACS in DICOM format. If the imaging modality doesn't support DICOM standard, the radiologist should convert it to DICOM format before sending it to the server. When clicking on this button, a new form will be invoked (Fig. 9) that allows inserting all the necessary information for the conversion process to complete.
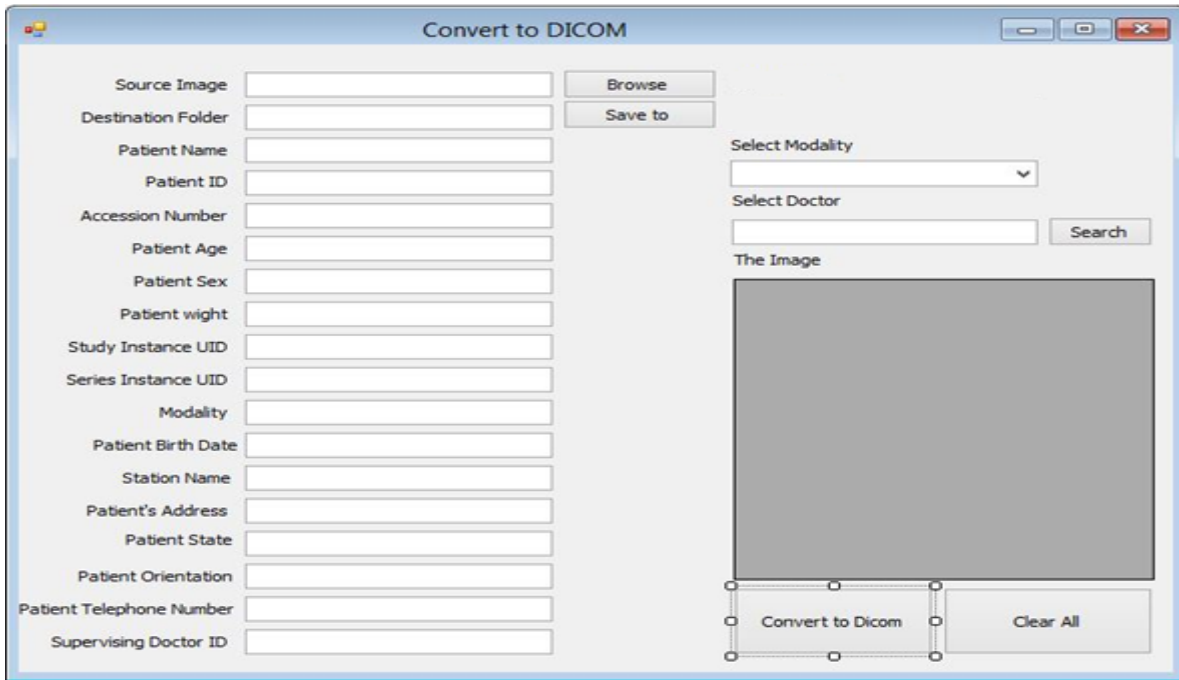
**Figure 5:** Convert to DICOM form

Here we can open an image file using the **Browse** button and associate patient's information to the images. After finishing the information entry process, we click the **Convert to DICOM** button then clicking the **Save to** button to save the file as a DICOM (.dcm) file in order to send it later to the server.

As example, suppose that a dermatologist taking pictures of patients' skin for treatment tracking using a digital camera. When we DICOMIZE an Image we wrap the image in a DICOM envelope and add important data that is required by the DICOM standard in order to enable all DICOM enabled applications to read and display the image correctly. We use RZDCX DICOM Toolkit to convert the image to a DICOM object. To convert a JPEG image to DICOM using RZDCX, we'll use the following

Three lines of C sharp code:

```
private void Convert_to_JPEG()
{
    DCXOBJ o = new DCXOBJ();
    string jpegImage = "my_image.jpg";
    o.SetJpegFrames(jpegImage);
}
```

Converting bitmaps is just as easy using the SetBMPFrames method:

```
private void Convert_to_Bitmap()
{
            DCXOBJ obj
            = new DCXOBJ();
            obj.SetBMPFrames(@"RZ-
            logo-new.bmp");
            obj.saveFile(@"RZ-logo-
            new.bmp.dcm");
}
```

## 4.1.2 Open DICOM

This form used to view and edit the DICOM file image and the data associated with it.
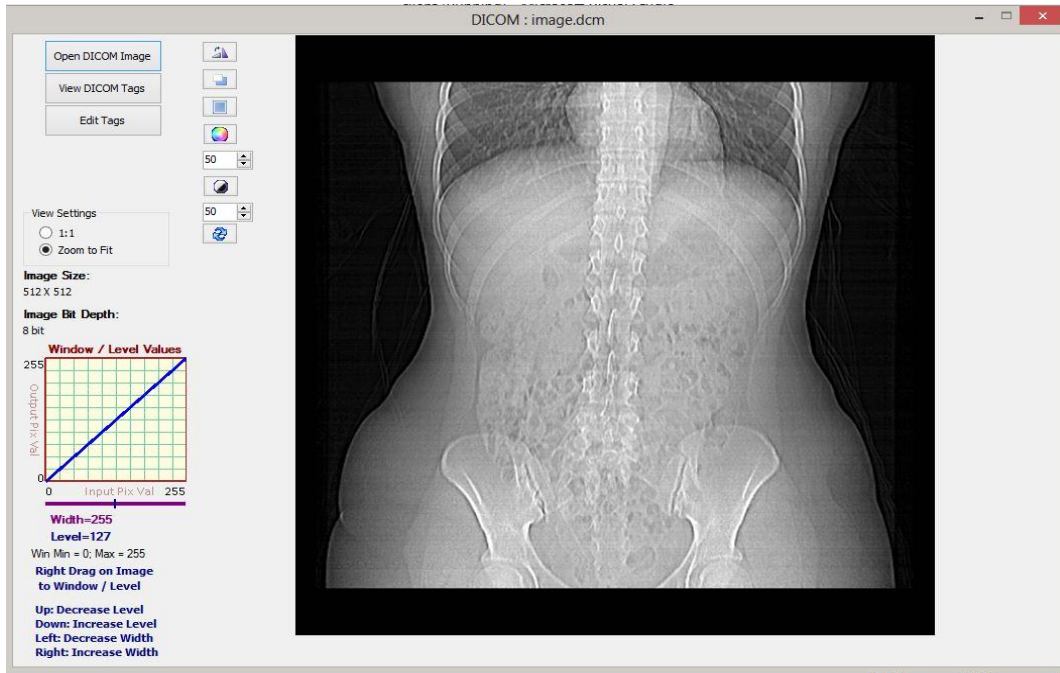
**Figure 6:** The DICOM viewer window

In this window we provide a number of image processing capabilities by using two ways:

a)   Edit image using mouse movement:

Edit Image level of coloring channels regarding to mouse movement .This effect calculates the mouse position and changes the levels of the image accordingly. To use this tool in the DICOM viewer window, we should press the mouse right click button and move it in any direction until we get the desired effect, as shown in the Figures below.
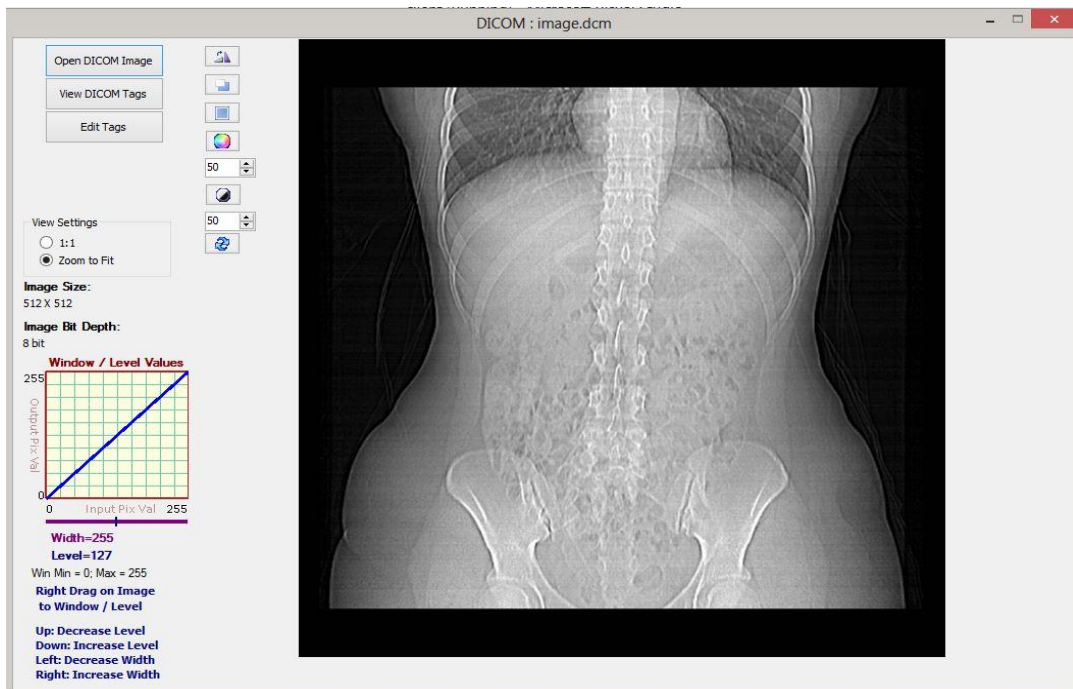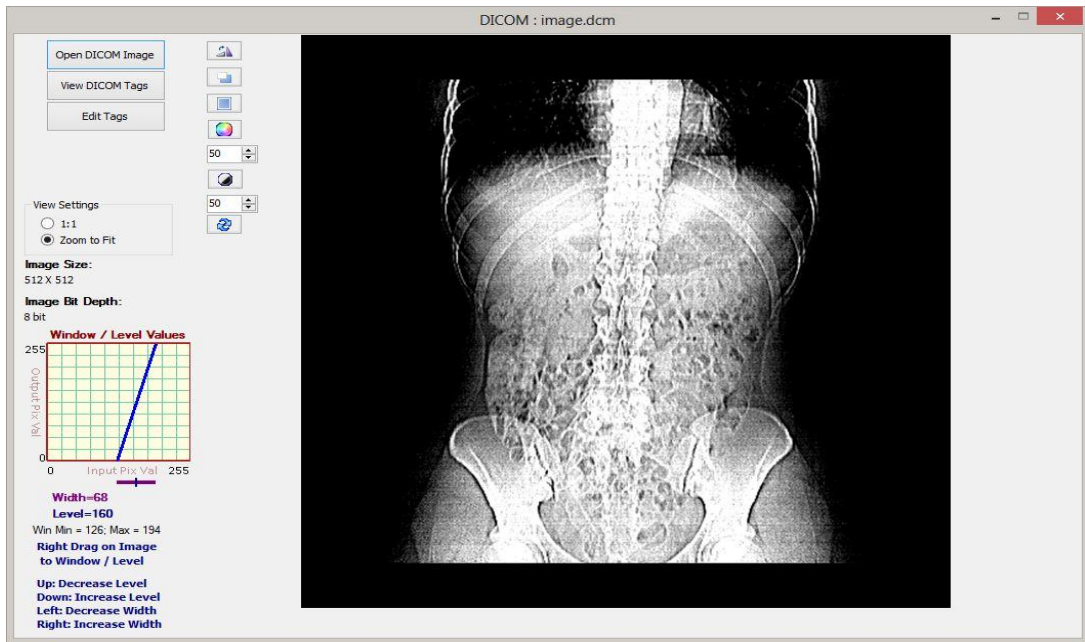


**Figure 7:** The image before the effect

**Figure 8:** The image after the effect
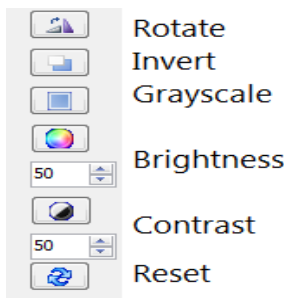
b)   Edit image using the editing toolbox:



**Figure 9:** Image editing tools

- Rotate: rotate image in clock wise direction.
- Invert: invert the colors of image (i.e. take 255-value of each pixel).
- Grayscale: transform the colored image into a grayscale image.

- Brightness.
- Contrast.
- Reset: restore the image to its original state.

**4.1.3 Compress DICOM**

Use lossless compression (implemented using zip algorithm) to reduce the size of the DICOM file before sending it to the server.

**4.1.4 Send DICOM**

Once we click the **Send DICOM** button, the following form will come up which give us the ability to connect to the server and upload the DICOM file to it.
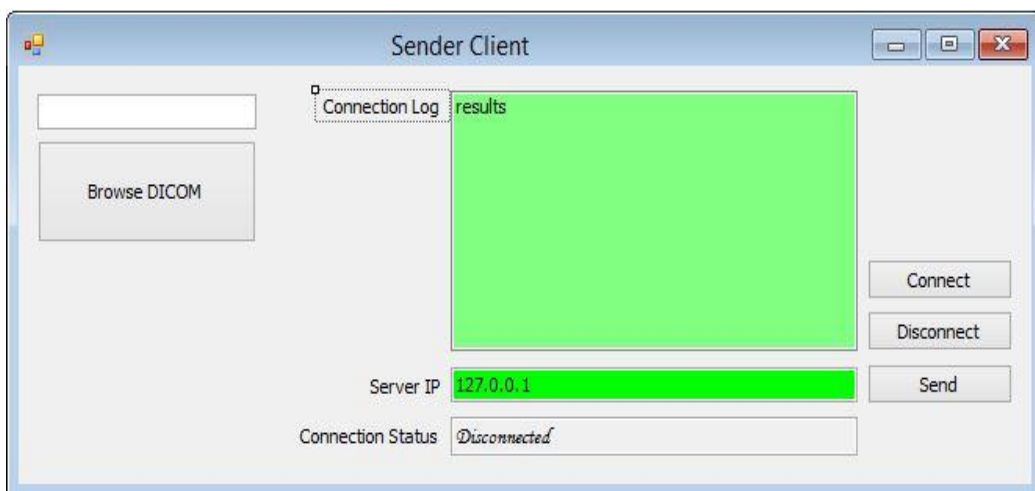


**Figure 10:** Send DICOM form

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When we want to communicate remotely with other hospitals using the internet or the intranet as the case may be, we need to acquire an internet protocol (IP) address for communication on the TCP/IP. In the green text box labeled **Server IP**, we enter the IP address of the server and then click the **Connect** button to establish communication with the server, and once it is established, we can browse to select the file by the **Browse DICOM** button and then click the **Send** button to send the file to the PACS server.

## 4.2 Archiving and management server Design (GUI and Functionality):

This software is designed to conform to the client-server architecture; hence the server serves as the coordinating point for all the users. The PACS server is the part of the project where it connects to multiple acquisition gateways (through a LAN) and manage the system. Once the admin launches the server for the first time, the following log in form comes up where he is prompted to supply his username and password.

**Figure 11:** Login Form

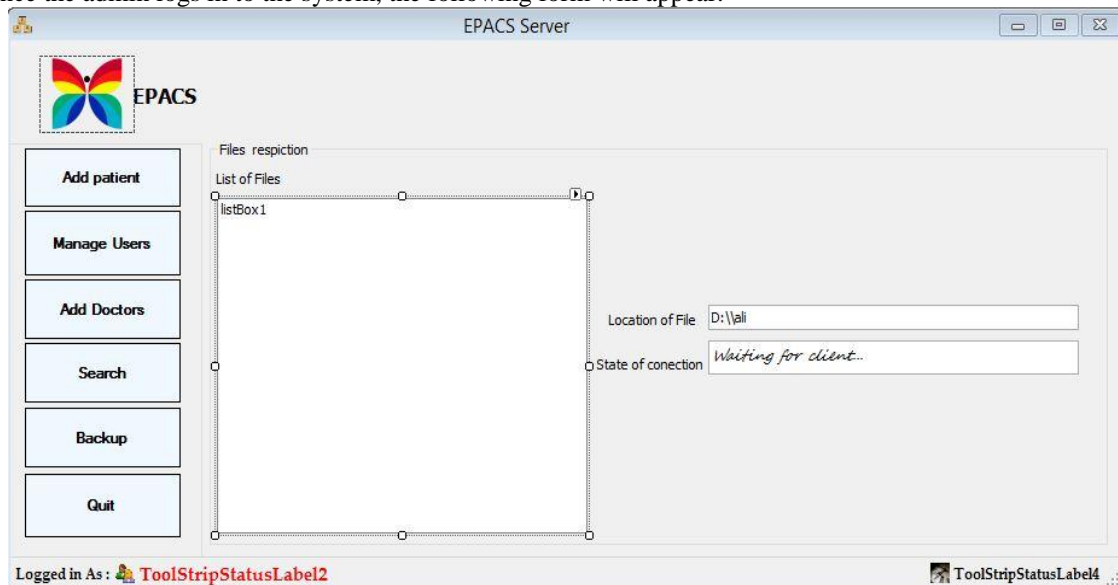Once the admin logs in to the system, the following form will appear.

**Figure 12:** Archiving Server and Management server

The main menu gives us the following capabilities:

### 4.2.1 Server operation:

The main functionality of this form is to wait for upcoming connections from the acquisition gateways to receive DICOM files. The Server will wait passively for acquisition gateways connections.

In case of more than one connection appear at the same time, they will be added to a queue and processed consecutively. The server has to be running to maintain the connection on the network. This window will appear once an upcoming connection takes place.
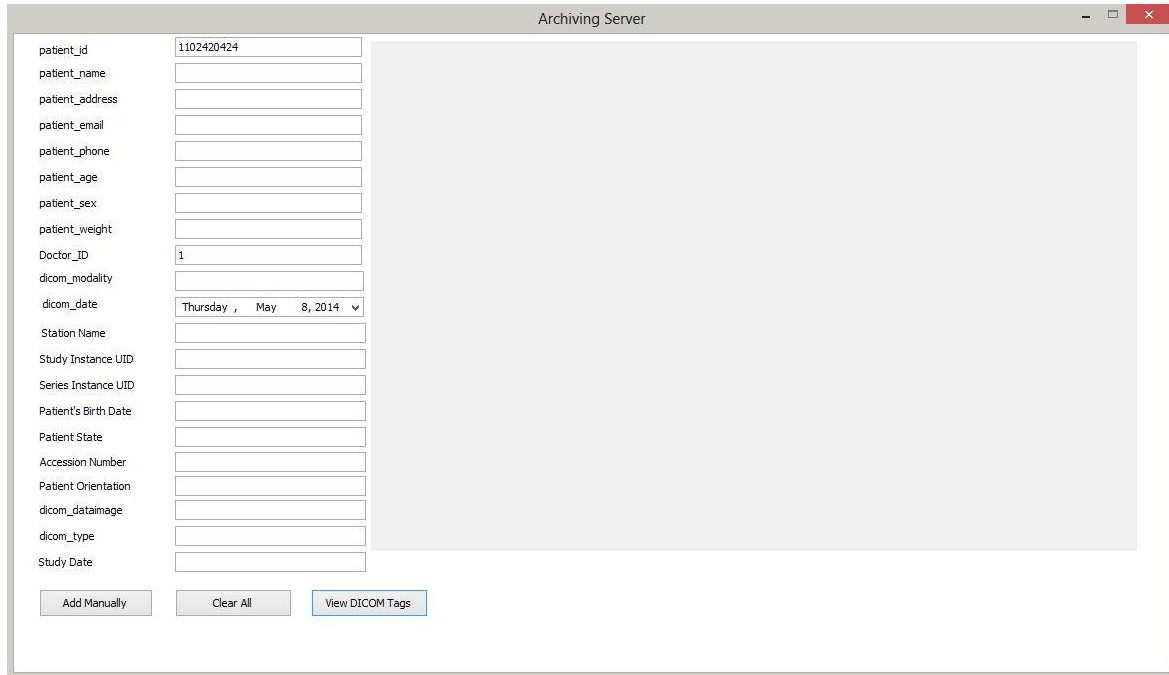


**Figure 13:** Archiving server window

This form works in two ways:

- **Automatically**: when it receives the DICOM file and accepts its associated information automatically regarding to a timer (notice that this method will work if the Admin doesn't change any information within the first10 seconds). The file will be added automatically to the database after the 10 seconds last.

- **Manually**: In contrast to the previous method, the server will receive the DICOM file and the admin will add or edit data to correct mistakes (before the first 10 seconds last) then he will add the file to the database by clicking the **Add Manually** button. A valid patient ID should be assigned to the image for searching it out at a later time and to avoid mix up of patient information.

### 4.2.2 Add patient:
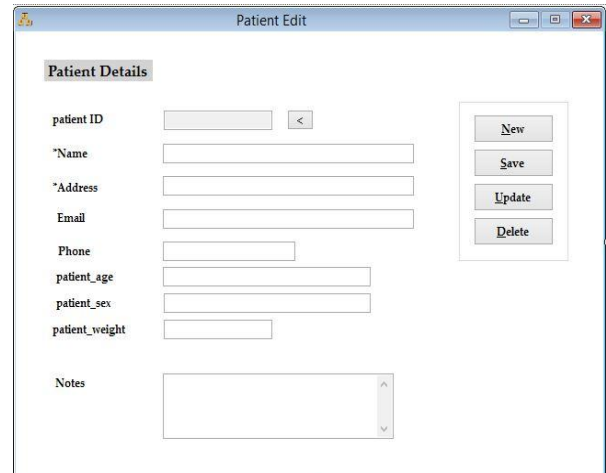
Is used to add patient information to the system.



**Figure 14:** Add patient window

In this window we can add, edit or delete patients from the database.

### 4.2.3 Manage Users:

This form can be used by the main administrator only, allowing him to add/delete Information Technicians to the server.

**Figure 15:** Add IT window

## 4.2.4   Add Doctors
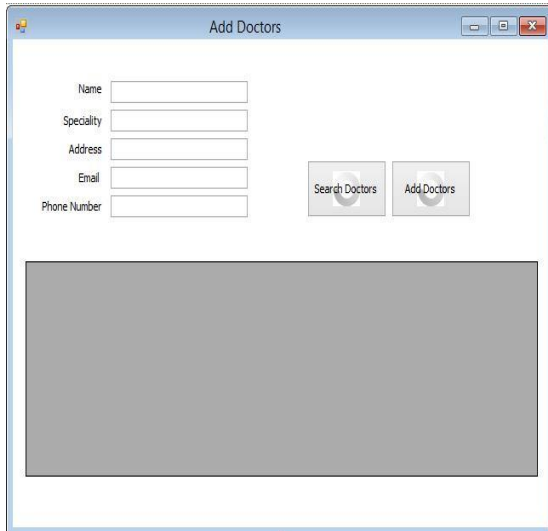
This window allows the admin to add doctors to the database.



**Figure 16:** Add doctor's window

## 4.2.5   Search

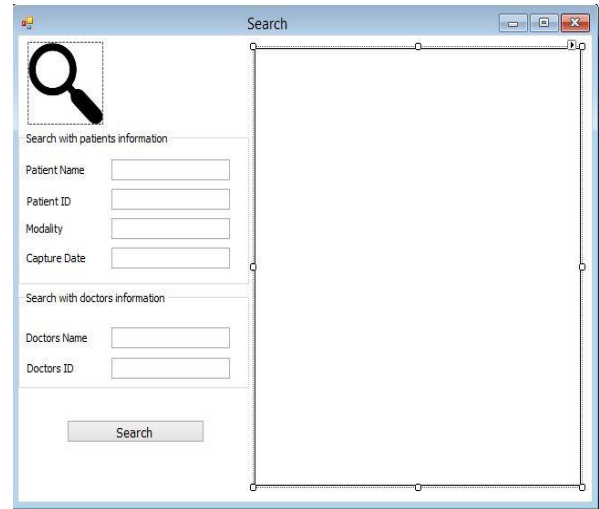This button allows the admin to search for DICOM files in the database.



**Figure 17:** Search for DICOM window

## 4.2.6   Backup

This button allows the admin to make a backup copy of the system database.
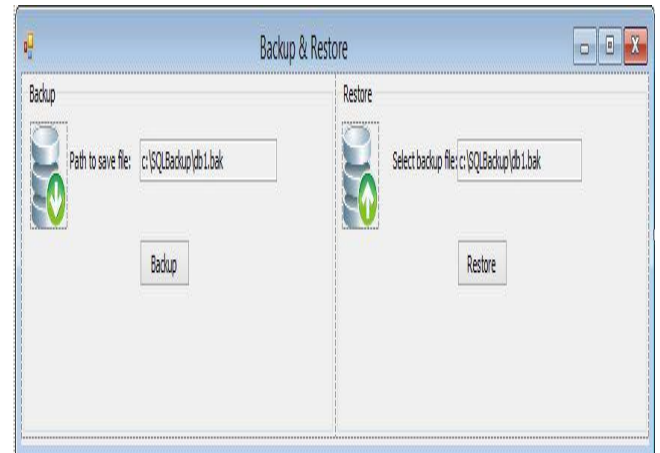


**Figure 18:** Backup and restore window

The left part make the database copy, and the right one restore the saved database.

## 4.3   Website Design (GUI and Functionality):

Here we present the website used by doctors/physicians to examine patients' reports and DICOM files and support in clinical decision-making (as with surgical planning).

### 4.3.1 Website Usage and Functionality

The log-in page has a secured access based on sessions and authentication methods.
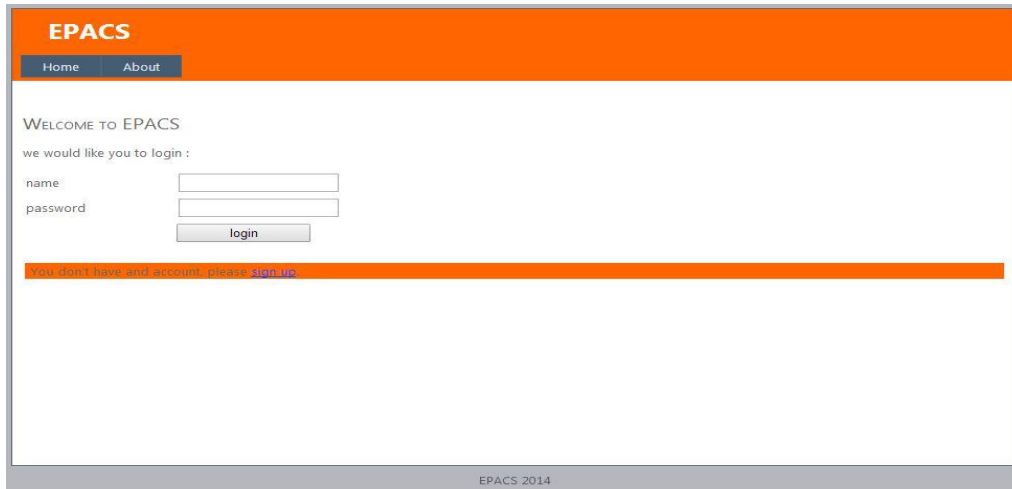
**Figure 19:** The log-in page

If the doctor doesn't have an account, he can request one by clicking on the **sign up** hyperlink, after that he will be taken to the **Sign-up** page to complete the registeration process.



**Figure 20:** The Sign-up page

After filling the required information, a message is sent to the doctor's email (since his email is stored in the Doctors table in the central database) to ensure his identity. Now the newly added doctor can go back to the homepage to login, which will take him to the welcome page.
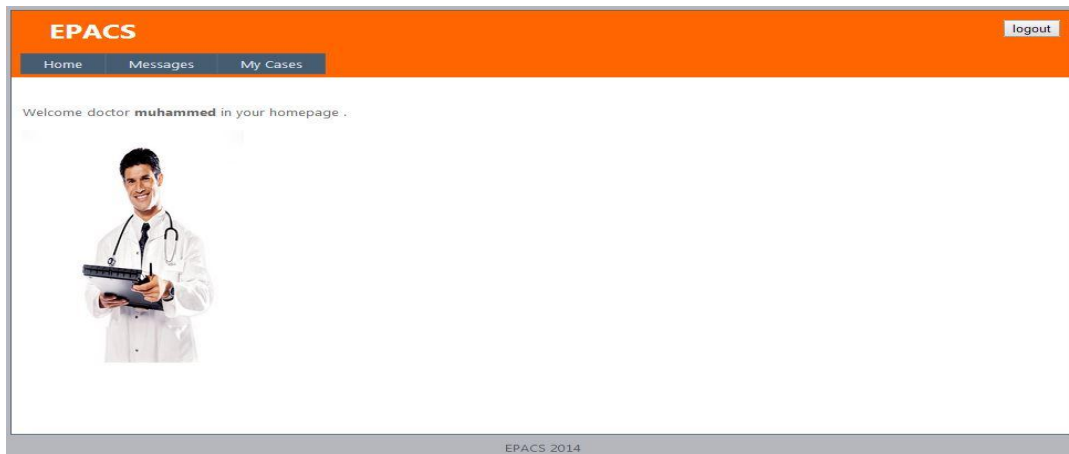


**Figure 21:** The Doctor Welcome page

Now the doctor can click the **My Cases** tab to see the different cases forwarded to him and do the following tasks:

- Examine an image file related to a specific patient, by clicking the **Show Image** button.
- View reports history.

- Search for a patient's related reports and images.
- Ask another doctor for a consultation, using the messaging system provided in the website.



**Figure 22:** My Cases page

In the Messages tab there is a messaging system with capability of showing and replying messag
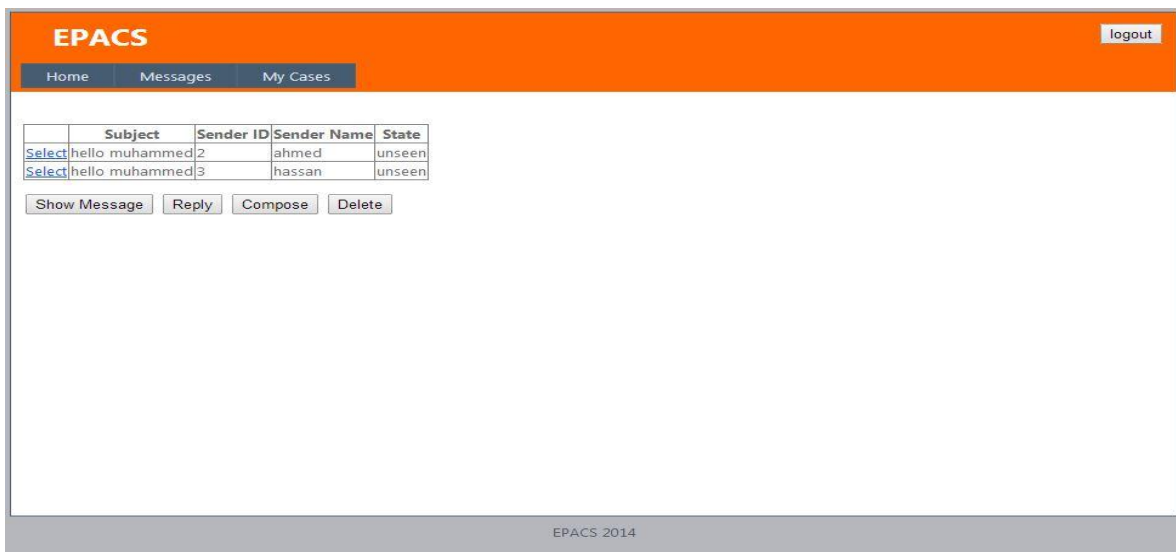


**Figure 23:** Messages Page

## 5. Conclusions

Our PACS system is an important part in a full medical institution management system that provides access to imaging files, patients' information and it reduces data redundancy and low image quality. The conclusions that were inferred from this project are:

1. Because outdated imaging modalities still being used in some hospitals, non-DICOM images are produced and they create difficulties in diagnosing.

Converting non-DICOM images to DICOM standard in the acquisition gateways solve this problem.

2. Manipulating images captured by the modalities in the acquisition gateways to ensure the quality of the captured images by providing a number of image processing tools.

3. Compressing the DICOM file before sending it to the server help to reduce its size on the database and the required transmission rate.

4. The transmitted file can be added to the database manually or automatically, meaning that there is no need for the presence of the system administrator near the server.

5. Providing a DICOM search mechanism in the server according to a number of different criteria.

6. Allowing the admin to make a backup copy of the system database.

7. Only doctors/physicians who are members of the specified hospital can have access to the PACS website.

8. The implemented messaging system will ease communication between physicians.

## 6. References

[1] Alberto Pastrana Palma, Juan Manuel Peña Aguilar, Luis Rodrigo Valencia Pérez, Alberto Lamadrid Álvarez, Juan Francisco Reyes Muñoz, Oscar Alonso Narvaéz Omaña and Marianela Talavera Ruz, ″Web-based Picture Archiving and Communication System for Medical Images″, IEEE Computing Society, Ninth International Symposium on Distributed Computing and Applications to Business, México, 2010.

[2] Nakintorn Patanachai, Bunyarit Uyyanonvara, Chanjira Sinthanayothin, Wichit Tharanon, Palakon Sompot and Krikamol Muandet, "PACS (Picture Archiving Communication System) for Dentistry", Proceedings of ECTI-CON 2008.

[3] Sherif E. Hussein, "Picture Archiving and Communication System Analysis and Deployment", 11th International Conference on Computer Modelling and Simulation, UKSim 2009.

[4] Yue Zhao, Zhiqiong Wang, Ying Han, Shijia Guo and Jianzhao Cao, "A Low-Load Architecture of Picture Automatic Archiving and Communication System", paper supported by the Science Foundation of Liaoning Province China, 2010.

[5] Oleg S. Pianykh, "Digital Imaging and Communications in Medicine (DICOM)", 2nd Edition, book, Springer, ISBN 978-3-642-10849-5, e-ISBN 978-3-642-10850-1, 2012.

[6] Maximilian Hecht, "PACS - Picture Archiving and Communication System", Vienna University of Technology, University of Paderborn, 2008.

[7] Alamu F.O., Emuoyibofarhe O. J and Oke A.O, "Developing a Robust Multimedia Picture Archiving and Communication System (PACS)", International Journal of Computer Applications (0975 – 8887), Volume 34– No.4, November 2011.

[8] Arjun Kalyanpur, Jasbir Singh and Ricky Bedi, "Practical issues in picture archiving and communication system and networking", Indian J Radiol Imaging, Vol 20, Issue 1, February 2010.

[9] Nasser N. Khmiss, Nehad Hameed Hussein, "Implementation of Web-based Management System for PACS Network", International Journal of Engineering Practical Research (IJEPR), volume 3, issue 1, February 2014.

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# تصميم وتنفيذ نظام ارشفة الصور والاتصال

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## الخلاصة:

ان نظام PACS (نظام ارشفة الصور والاتصال) قدُ قدم الى حد كبير كبديل موثوق عن الطرق التقليدية المتبعة في أنظمة الرعاية الصحية والمقصود بها الأفلام الطبية والنظام الورقي. لقد تم استحداث هذا النظام منذ بضعة سنوات وصار جزءا لا يتجزأ من البنية التحتية لأقسام التصوير الطبي والشعاعي في مختلف انحاء العالم. ان الخدمات الطبية التي يقدمها هذا النظام تساعد في تشخيص العديد من الحالات المرضية بشكل دقيق وسريع. كما ان هذا النظام يساعد في تعليم طلبة كليات الطب عن الصور الشعاعية كما انه يقلل الزمن اللازم لتشخيص الحالات ونقل وارسال الصور الخاصة بالمريض عبر شبكة حاسوبية لغرض التشاور مع فريق طبي متخصص وذلك لغرض تشخيص الحالة بشكل ادق .

في هذا البحث نناقش كيفية تصميم وبناء هذا النظام في المستشفيات التي تتوافر فيها وسائل الخزن الالكترونية لاستعادة ومعالجة وتوزيع وعرض الصور الطبية باستخدام نسق ال DICOM. كما وقد تم إضافة خصائص جديدة للنظام.

تم تحقيق الأهداف المطلوبة من العمل وهي تحويل الصور بمختلف النُسق الى نَسق ال DICOM كما وتم تقليل الزمن المطلوب لنقل الصور والمساحة المطلوبة لتخزينها. تم تنفيذ هذا النظام باستخدام برنامج Visual Studio .

## الكلمات المفتاحية:

نظام ارشفة الصور والاتصال، أجهزة التصوير الطبي، صور طبية، اشعة، تحويل الصور، DICOM

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