Sudan University of Science and Technology

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Design of dynamic webpage for medical image exploration

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Biomedical Engineering

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الآيـــه

قال الله تباركَ وتعالى في مُحكَمِ تنزِيلِه :

{وَلَسَوْفَ يُعْطِيكَ رَبُّكَ فَتَرْضَى }

"صدق الله العظيم"
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Dedication

To our respected parents for their support and continuous care, without whom none of our success would be possible.

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First and foremost, we would like to thank God for bringing us this far. We would be nowhere without Him.

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Abstract

In this research we discussed the design and implementation of dynamic web page for medical image exploration by the using of small XAMPP sever that include apache server executed inside the browser and connect the web application through local area network LAN.

We proposed a wavelet based image compression technique on which two-dimensional discrete wavelet transform is used to decompose the image and the wavelet coefficients are transmitted by entropy encoding after thresholding to reduce transmission time, storage cost and capacity.

The performance of compression was measured using objective measures such as compression ratio, mean square error and peak signal to noise ratio.

المستخلص

يناقش هذا البحث تصميم و تطبيق صفحة تفاعلية (dynamic webpage) لعرض وتحليل وارسال الصور الطبية بعد معالجتها عن طريق خادم شبكي و ربط الصفحة بشبكة محلية (LAN) .

تم اقتراح تقنية (Wavelet) لضغط الصور الطبية بغرض تقليل مساحة التخزين المستهلكة وتسريع عملية الإرسال , تم الحصول على نسبة ضغط 83.3% مع المحافظة بقدر الامكان على جودة الصورة بعد فك الضغط , وتم قياس جودة عمليات معالجة الصور الطبية بإستخدام معاملات (MSE)و(PSNR)

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List of abbreviations

ACR	American College of Radiology
BootP	Bootstep Protocol
CR	Compression Ratio
CT	Computer Tomography
DCT	Discrete Cousin Transform
DWT	Discrete Wavelet Transform
DHCP	Dynamic Host Configuration
HIS	Hospital Information System
ISO	International Standers Organization
LAN	Local Area Network
MRI	Magnetic Resonance Imaging
NEMA	National Electrical Manufacturer Association
NIC	Network Interface Card
OSI	Open System interconnection
PACS	Picture Archiving and Communication System
PSNR	Peak Signal to Noise Ratio
RIS	Radiology Information System
TCP/IP	Transmission Control Protocol /Internet Protocol
WAN	Wide Area Network
WWW	World Wide Web

Chapter One

Introduction

1.1 Introduction

Telemedicine is the use of electronic information and communications technologies to provide and support health care when distance separates the participants. An important part of telemedicine is Teleradiology which is radiology concerned with the transmission of digitized medical images (as X-rays, CT scans, etc.) over electronic networks and with the interpretation of the transmitted images for diagnostic and educational purposes. The managed care trend in healthcare delivery expedites the formation of teleradiology expert centers. However, even without health care reform, teleradiology is still an extremely important component in radiology practice for the following reasons. First, teleradiology secures images for radiologists to read so that no images will be accidentally lost in transit. Second, teleradiology reduces the reading cycle time from when the image was formed to when the report is completed. Third, because radiology is subdivided into many subspecialties, a general radiologist requires an expert's second opinion on occasion. The availability of teleradiology will facilitate seeking a second opinion. Fourth, teleradiology increases radiologists' income because no images are accidentally lost and subsequently not read. The development of the Internet and the World Wide Web (WWW) has created new perspectives of data communication around the world. Picture archiving and communication systems (PACS) are usually built based on DICOM standards and are often implemented in a private network for privacy and security issues.

DICOM stand for Digital Image and Communication in Medicine. It used to handle, store, print and transmit information. DICOM supports special protocol for communication over network and has certain file format.

All current digital image-acquisition devices produce DICOM images and communicate through DICOM networks. DICOM does not only store the images, but it also records a multitude of other image-related parameters such as physical sizes of objects in the image, slice thickness or image exposure parameters. These data enrich the informational content and facilitate interpretation and post-processing of medical images. [1]

The first digital images were produced by nuclear medicine, angiography and computed tomography (CT) equipment. [2] The development of the DICOM standard is based on the cooperation of the American College of Radiology (ACR) with the National Electrical Manufacturers Association(NEMA). In 1983 a joint committee was founded to create a possibility for data transfer regardless of manufacturers' standards and to facilitate the development and expansion of Picture Archiving and Communication Systems (PACS). PACS stands for Picture Archiving and Communication Systems. Networks and devices dedicated for storage, archiving, and presentation of medical image can be called PACS. With help of PACS, soft copy of image can be created and communicated between different hardware using standard like DICOM. The header portion would contain a description of the image along with the data elements (such as patient name) identifying it. A concept of using data elements of variable length identified with a tag or key (the name of the element) was thought to be particularly important and was adopted by the committee. After 2 years of work, the first version of the standard, ACR-NEMA 300-1985 (also called ACR-NEMA Version 1.0) was distributed at the 1985 RSNA annual meeting and published by NEMA. As with many first versions, errors were found and improvements were suggested. The committee had empowered Working Group (WG) VI to follow up on the standard after it was published. This WG answered many questions from potential developers and began working on changes to improve the standard. In 1988, ACR-NEMA 300-1988 (or ACR-NEMA Version 2.0) was published. It used substantially the same hardware specification as Version 1.0, but it added new data elements and fixed several errors and inconsistencies. The problem was that by 1988 many users wanted an interface between imaging devices and a network. While this could be accomplished with Version 2.0, the standard lacked the parts necessary for robust network communication. For example, one could send a device a message that contained header information and an image, but one would not necessarily know what the device would do with the data. Since ACR-NEMA Version 2.0 was not designed to connect equipment directly to a network, solving these problems meant major changes to the standard. The committee had very early adopted the idea that future versions of the ACR-NEMA Standard would retain compatibility with the earlier versions, and this placed some constraints on WG VI. In a decision of major importance for the standard, it was decided that developing an interface for network support would require more than just adding patches to Version 2.0. The entire design process had to be re-engineered, and the method adopted was that of object-oriented design. Later sections will describe this process briefly.

In addition, a thorough examination of the types of services needed to communicate over different networks showed that defining a basic service would allow the top layer of the communications process (the application layer) to talk to several different network protocols. These protocols are modelled as a series of layers, often referred to as "stacks." The existing Version 2.0 stack that defined a point-to-point connection was one. Two others were chosen based on popularity and future expansion: The Transmission Control Protocol/Internet Protocol (TCP/IP) and the International Standards Organization Open Systems Interconnection (ISO-OSI). The basic design philosophy was that a given medical imaging application (which is outside of the scope of the standard) could communicate over any of the stacks to another device that used the same stack. With adherence to the standard, it would be possible to switch the communications stacks without having to rewrite the computer programs of the application. [3].

Data sharing in medical imaging enables entitled healthcare professionals, administrators and citizens to access medical images and image related data, with this sharing not being dependent on the place or time. Evolution of information technology also opened new horizons for diagnostic image processing after their acquisition. This evolution motivated academic radiologists to work out universal standard for digital images in medicine which could allow archiving and retrieval of different exams and communication of image data, where the universal standard for images was not dependent on the equipment vendor. [4]

Medical images can be viewed inside a Web browser with use of a small program known as the DICOM Viewer which offers several advantages over more traditional picture archiving and communication systems (PACS): It is easy to install, maintain and significant running costs, is platform independent, allows images to be display and manipulated efficiently, and is easy to integrate with existing systems that are already making use of Web technologies.

The simplicity and flexibility of Internet technologies makes them highly preferable to the more complex PACS workstations. DICOM datasets are huge, which cause considerable storage problems as well as transferring difficulties. With the growing number of medical examinations, storage requirements become necessary. [5]

Medical records must be stored for a minimum amount of time, usually between 5 to 10 years. For an average hospital of 300 to 500 beds this requires up to 40 terabytes of storage, resulting in huge digital data archives, which are expensive and difficult to maintain. Data compression can reduce storage requirements by 60% and more, without losses, this effectively halves the long-term storage costs Because of this, compression of DICOM files is frequently applied. [6]

Communication network used for the transmission of images and related data from the acquisition site to the expert center for diagnosis. Because most teleradiology applications are not within the same hospital complex, but through inter healthcare facilities in metropolitan areas or at longer distances, the communication technology involved requires WAN technology. Teleradiology requires image compression because of the slow speed and high cost of using WAN. [7]

For lossless image compression, current technology can achieve between 3:1 to 2 :1 compression ratios, whereas in lossy compression using cosine transform-based MPEG and JPEG hardware or software, 20: 1 to 10: 1 compression ratios can be obtained with acceptable image quality. The latest advance in image compression technology is the wavelet transform, which has the advantages over cosine transform of higher compression ratio and better image quality; however, hardware wavelet compression is not yet available.

Some web-based teleradiology systems use a progressive wavelet image compression technique. In this technique, image reconstruction from the compressed file is performed in a progressive manner in that a lower-resolution image is first reconstructed almost instantaneously and displayed on request. The user would have the psychological effect that the image is transmitted through the network almost in real time. Higher-quality images are continuously reconstructed to replace the previous ones until the original image is reconstructed and displayed. Another method is only reconstructing a region of interest instead of full image. With advances in communications technology, image workstation design, and image compression, teleradiology has become as an integrated diagnostic tool in daily radiology practice.

Web-based teleradiology is mostly used by hospital or larger clinics to distribute images to various parts of a hospital or clinic or outside the hospital. A web server is designed in which filtered images from PACs systems are either pushed from the PACS server or pulled by the web server. Filtered images mean that the web server has a predetermined directory to manage the image distribution based on certain criteria like what types of images to where and to whom. The clients can view these filtered images from workstations connected to the web server. The clients can be referring physicians who just want to look at the images or radiologists who need to make a remote diagnosis. Web-based teleradiology is very convenient and low cost to set up because most technologies are readily available, especially within the hospital intranet environment. [8]

1.2 Problem statement

All modalities in radiology practice have become digital and therefore deal with DICOM image, the large size of file that store on memory or any physical storage consume large space and this affect the total cost of the system, the transmission speed and performance, also supercomputer used by the radiologists to visualize and analysis the images, unfortunately have higher cost to pay and annually running costs not to mention the maintenance costs.

1.3 Objectives

The aim of this research is to create a Web based medical image exploration to eliminate the higher cost and unavailability of the Supercomputer with storage space to store and retrieve of medical images, and reduce storage space by using lossless compression algorithm used to compress the DICOM images probably without losing data that affects the diagnosis of the images where the users can friendly access to the medical images to analysis and visualize the image.

1.4 Method

With the advent of filmless radiology, it becomes important to be able to distribute radiologic images digitally throughout an entire hospital. A new approach based on World Wide Web technologies was developed to accomplish this objective. After acquisition of the radiologic images it will be pass through several tasks, firstly is designing of DICOM web-based viewer, this approach involves a Web server that allows the query and retrieval of images stored in a Digital Imaging and Communications in Medicine (DICOM) archive. By using of a small XAMPP server that include apache server inside it which is executed inside the browser, then the images can be viewed inside a Web browser. It is easy to install and maintain, is platform independent, allows images to be manipulated and displayed efficiently, and is easy to integrate with existing systems that are already making use of Web technologies.

secondly the pre-processing is to increase the images quality before compression the image to achieve a proper constructed image from the compressed image using the discrete wavelet transform technique for composition the radiologic image, hence the objective of radiologic image compression is to reduce the data volume and to achieve a low bit rate in the digital representation of radiologic images without perceived loss of image quality.

The third task is to make this local-host viewer server available through local area network (LAN), we can connect this server locally, by install the server on one computer (central computer), this central computer is connected to hub (switch) and connect another computer to the switch, therefore you can access the DICOM viewer using the IP of central computer and the same gateway.

1.5 Thesis Layout

Chapter 1: give general view of DICOM history and the evolution of web applications used for DICOM viewing, problem and thesis statement, also brief method of methods used in thesis.

Chapter 2: discusses published information in web pages and applications for medical images viewing, and image processing techniques used for medical images compression.

Chapter 3: give detailed view of methods, software languages used in designing web page and type of network, also image compression and enhancement techniques

Chapter 4: this chapter reflect all results reached in our research.

Chapter 5: shows discussion of results were found and short conclusion of our work and result also future recommendation.

Chapter Two

Literature review

2.1 Literature review

Telemedicine allows clinical services to leverage information technologies, video imaging, and telecommunication linkages to enable doctors to provide healthcare services at distance.

Web technologies emerged rapidly during the last decade and enabled fast and reliable access to all kinds of information. Nowadays web applications got all prerequisites to compete with traditional desktop applications. The aspect of platform independence and accessibility from almost every device makes web applications even more promising for the future. Since software used for medical applications is commonly proprietary and mostly limited to a specific operating system, the combination of web technologies together with the DICOM standard is a natural next step. With the advent of filmless radiology, it becomes important to be able to distribute radiologic images digitally throughout an entire hospital.

A new approach based on World Wide Web technologies was developed to accomplish this objective. This approach involves a Web server that allows the query and retrieval of images stored in a Digital Imaging and Communications in Medicine (DICOM) archive, image scan be viewed inside a Web browser.

Several hospitals around the world have now realized the great potential of using digital images instead of using analog cellulose acetate [9], because of the ability of filtering, storing and transmitting digital images. moreover, web-based applications

as opposite to pre-installed software offer multi-platform technology that allows people from different places worldwide to be able to access such system. over the past few years, Picture Archiving and communication Systems (PACS) have welcomed web-based technologies and opened their horizons to a new digital age of radiology. [10] With the advent of filmless radiology, it becomes important to be able to distribute radiologic images digitally throughout an entire hospital. A new approach based on World Wide Web technologies was developed to accomplish this objective. This approach involves a Web server that allows the query and retrieval of images stored in a Digital Imaging and Communications in Medicine (DICOM) archive. The image scan be viewed inside a Web browser with use of a small Java program known as the DICOM Java Viewer, which is executed inside the browser. The system offers several advantages over more traditional picture archiving and communication systems (PACS): It is easy to install and maintain, is platform independent, allows images to be manipulated and displayed efficiently, and is easy to integrate with existing systems that are already making use of Web technologies. Progressive transmission of medical images through Internet has emerged as a promising protocol for teleradiology applications. The major issue that arises in teleradiology is the difficulty of transmitting large volume of medical data with relatively low bandwidth. [11]

Teleradiology is a subset of telemedicine dealing with the transmission and display of images, in addition to other patient-related information, between a remote site and an expert center. The technology requirement for teleradiology is more stringent than that of general telemedicine because the former involves images. Basically, telemedicine without teleradiology requires only very simple technology: A computer gathers all necessary patient information, examination results, and diagnostic reports, arranges them in proper order with or without a standard format at the referring site, and transmits them through telecommunication technology to a second computer at the expert center where the information is displayed as soft copy on the monitor. In modern hospitals or clinics, the information gathering and the arrangement of the information in proper order can be handled by the hospital information system (HIS).

When the teleradiology service requires a patient's historical images as well as related information, teleradiology and PACS become very similar. The major difference between them is in the methods of image capture. Some current teleradiology operations still use a digitizer as the primary method of converting a film image to digital format, although the trend is moving toward DICOM standard. In PACS, direct digital image capture using DICOM is mostly used. In networking, teleradiology uses slower-speed wide area networks (WAN) compared with the higher-speed local area network (LAN) used in PACS. In Teleradiology, image storage is mostly short term, whereas in PACS it is long term. Teleradiology relies heavily on image compression, whereas PACS may or may not.

Historically, telemedicine can be traced back to the mid to late 19th century with one of the first published accounts occurring in the early 20th century when electrocardiograph data were transmitted over telephone wires. Telemedicine, in its modern form, started in the 1960s in large part driven by the military and space technology sectors, as well as a few individuals using readily available commercial equipment. Examples of early technological milestones in telemedicine include the use of television to facilitate consultations between specialists at a psychiatric institute and general practitioners at a state mental hospital, and the provision of expert medical advice from a major teaching hospital to an airport medical Centre.

The literature reports that while telemedicine offers great opportunities in general, it could be even more beneficial for underserved and developing countries where access to basic care is of primary concern. One of the biggest opportunities telemedicine presents is increased access to health care. Providing populations in these underserved countries with the means to access health care has the potential to help meet previously unmet needs and positively impact health services. Telemedicine applications have successfully improved the quality and accessibility of medical care by allowing distant providers to evaluate, diagnose, treat, and provide follow-up care to patients in less-economically developed countries. They can provide efficient means for accessing tertiary care advice in underserved areas. By increasing the accessibility of medical care telemedicine can enable patients to seek treatment earlier and adhere better to their prescribed treatments, and improve the quality of life for patients with chronic conditions. Telemedicine has been advocated in situations where the health professional on duty has little or no access to expert help; it is able to offer remote physician access to otherwise unavailable specialist opinion, providing reassurance to both doctors and patients. Telemedicine programmers have been shown to directly and indirectly decrease the number of referrals to off-site facilities and reduce the need for patient transfers. Remote care and diagnosis via telemedicine in less-economically developed countries thus benefits both patients and the health care system by reducing the distance travelled for specialist care and the related expenses, time, and stress. Furthermore, telemedicine programmers have the potential to motivate rural practitioners to remain in rural practice through augmentation of professional support and opportunities for continuing professional development.

Telemedicine networks in developing countries could also offer secondary benefits. Telecommunication technologies, such as those used in telemedicine initiatives, have shown to be effective tools for connecting remote sites. By opening new channels for communication telemedicine connects rural and remote sites with health-care professionals around the world, overcoming geographical barriers.

This can lead to increased communication between health service facilities, and facilitate cross-site and inter-country collaboration and networking. Such collaborations can support health-care providers in remote locations through distance learning and training.

Telemedicine also provides opportunities for learning and professional development by enabling the provision and dissemination of general information and the remote training of health-care professionals. As Zbar and colleagues asserted, “Telemedicine creates a university without borders that fosters academic growth and independence because the local participating surgeons have direct access to experts in the developed world.” [12] For example, referred specialists have reported value in terms of medical education through the provision of consultation. It is important to note that such partnerships provide mutual benefits. For example, health-care providers in developed nations are provided with an opportunity to learn to treat neglected diseases, which they very seldom see in person. The knowledge sharing that occurs because of inter-site collaboration may be formal or informal and has shown to aid health-care professionals in overcoming the professional isolation that they often face in remote areas, and to improve their skills and the services they offer. A telemedicine program to support maternal and neonatal health in Mongolia exemplifies many of these points.

A compression of medical imagery is an important area of biomedical and telemedicine. In medical image compression diagnosis and analysis are doing well simply when compression techniques protect all the key image information needed for the storage and transmission. A large amount of medical data is generated through advanced medical imaging modalities. The digitization of medical image information is of immense interest to the medical community to reduce transmission time, storage costs, and for implementation of the e-healthcare system like telemedicine. Essentially, there are two types of image compression: 1. ‘‘Lossless’’ or reversible compression. 2. ‘‘Lossy’’ or irreversible compression. In lossless or reversible compression, there is no loss of information in the compressed image data. Furthermore, lossless compression does not involve the process of quantization but makes use of image transformation and encoding to provide a compressed image.

This type of compression is of limited application in digital radiology, for reasons mentioned earlier. Lossy or irreversible compression involves at least three steps; image transformation, quantization, and encoding. As noted by Erickson [13] ‘‘transformation is a lossless step in which the image is transformed from gray scale values in the spatial domain to coefficients in some other domain”. One familiar transformation is the Fourier Transform used in reconstruction magnetic resonance images (MRI). Other transforms such as the discrete cosine transform (DCT) and the discrete wavelet transform (DWT) are commonly used for image compression. No loss of information occurs in the transformation step. Quantization is the step in which the data integrity is lost. It attempts to minimize information loss by preferentially preserving the most important coefficients where less important coefficients are roughly approximated, often as zero. Quantization may be as simple as converting outing point values to integer values. Finally, these quantized coefficients are compactly represented for efficient storage or transmission of the image. [14]

There is no doubt in the radiologic literature that the use of irreversible compression is receiving more and more attention as a means of reducing the le size of diagnostic digital images, to reduce storage and decrease image transmission times. Irreversible compression methods can provide greater compression ratios compared to lossless compression methods, ‘‘but do not perfectly reproduce the original image. However, the reproduction may be good enough that there is no perceptible image degradation nor compromised diagnostic value’’. [15] The basis for this approach stems from Goldberg's notion that ‘‘compression will have to be optimized based on the type of image being processed’’. [16]

Several studies have been conducted to examine the effect of various compression ratios on the quality of images presented to the radiologist for interpretation either for primary diagnosis or for general clinical review after the primary diagnosis has been reported. The nal paper to be cited in this section of the literature review is one by Michael Tobin MD, [17]In this study Dr. Tobin compared both lossless and lossy compression on two archived image types used in radiology, one that is characterized by high spatial resolution (bone radiograph) and the other by high contrast resolution (abdominal CT image), While the bone image showed scleroderma, the CT image showed polycystic kidney disease. The evaluation methodology utilized in the assessment of observer performance is qualitative rather than quantitative. This methodology was selected ‘‘because radiologists typically evaluate images qualitatively in their day-to-day practice and, also, because common metrics used for comparing images pre-and post-compression, e.g. mean pixel error, root mean-square error, maximum error, etc., may not correlate well with visual assessment of image quality’’. After a comprehensive comparison of images compressed with wavelet versus those compressed with JPEG with DCT, with image degradation appearing sooner for wavelet compression than for JPEG, the author makes the following statement ‘‘Because the level of compression that preserves clinically acceptable image quality may depend on the modality, the anatomy, and the pathology, the author recommended lossless wavelet or JPEG compression algorithms for medical image archiving''

much efficient than DCT in quality and efficiency wise but in performance time wise DCT is better than DWT [15] Swastik Das et al. presented DWT and DCT transformations with their working. They concluded that image compression is of prime importance in Real time applications like video conferencing where data are transmitted through a channel. Using JPEG standard, DCT is used for mapping which reduces the inter pixel redundancies Anil Kumar et al. in their paper two image compression techniques namely, DCT and DWT are simulated. They concluded that DWT technique is reduced using optima code word having minimum average length. In JPEG 2000 standard of image compression DWT is used for mapping, all other methods remaining same. They analyzed that DWT is more general and efficient than DCT [18]

The studies reviewed in this paper essentially show the following: (a) Image types in digital radiology are different based on their mode of generation, as well as their spatial and contrast resolution, determined by their matrix size/pixel size, and bit depth, respectively. Only static gray scale images (as opposed to color images) have received more attention in the literature as well as dynamic angiographic grayscale images. (b) There are several forms of irreversible compression and they are not all equal in terms of performance. Irreversible compression algorithms studied in the papers cited include JPEG (DCT), wavelet-based (DWT), advanced wavelet schemes such as SPIHT, and the more recent lossy compression scheme, JPEG 2000. (c) Some types of images such as digitized chest images, CT, MRI and ultrasound images have different ''compression tolerance'' and therefore a single compression ratio cannot be assigned to a modality, even for a given organ system. Chest images for example can be compressed at ratios as high as 20:1 using CR and DR without compromising image quality. Other image types such as CT images for example can be compressed at ratios as high as 20:1 in the detection of coronary artery calcination. (d) The evaluation methods used to measure observer performance on various detection tasks (identifying structures and lesion detection) included numerical analysis, subjective assessment of image quality, and objective methods, most notably, the ROC methodology. (e) JPEG 2000 is much more efficient at image compression compared to JPEG, at higher compression ratios. (f) The results of these studies would appear to indicate that image compression in digital radiology would have to be optimized based on the types of images being generated, interpreted for primary diagnosis, stored, and transmitted to remote sites for clinical review by physicians other than radiologist, it is important to note the viewpoint of one of the foremost authority on irreversible compression of medical images, Dr.Bradley Erickson, MD., PhD, of the Department of Radiology, Mayo Foundation, Rochester, [13]states that: ‘‘Irreversible compression appears to be a very effective means of decreasing image le size to facilitate storage and transmission of radiologic images. There is increasing evidence that some forms of irreversible compression can be used with no measurable degradation in aesthetic or diagnostic value. It is increasingly necessary for radiologists to become conversant with compression techniques and their effects on images. Using irreversible compression in everyday practice can reduce significantly the cost of delivering radiology services by reducing the information infrastructure required to deliver and store images’’.

Chapter Three

Theoretical background

3.1 Introduction to TCP/IP

TCP/IP is the suite of protocols used by the Internet and most LANs throughout the world. In TCP/IP, every host (computer or other communications device) that is connected to the network has a unique IP address. An IP address is composed of four octets (numbers in the range of 0 to 255) separated by decimal points. The IP address is used to uniquely identify a host or computer on the LAN. For example, a computer with the hostname Morpheus could have an IP address of 192.168.7.127. You should avoid giving two or more computers the same IP address by using the range of IP addresses that are reserved for private, local area networks; this range of IP addresses usually begins with the octets 192.168.

3.1.1 LAN network address

The first three octets of an IP address should be the same for all computers in the LAN. For example, if a total of 128 hosts exist in a single LAN, the IP addresses could be assigned starting with 192.168.1.*x*, where *x* represents a number in the range of 1 to 128. You could create consecutive LANs within the same company in a similar manner consisting of up to another 128 computers. Of course, you are not limited to 128 computers, as there are other ranges of IP addresses that allow you to build even larger networks. There are different classes of networks that determine the size and total possible unique IP addresses of any given LAN. For example, a class A LAN can have over 16 million unique IP addresses. A class B LAN can have over 65,000 unique IP addresses. The size of your LAN depends on which reserved address range you use and the subnet mask (explained later in the article) associated with that range (see Table 1.).

Table* 3.1*:* *Address ranges and LAN sizes

Address range	Subnet mask	Provides	Addresses per LAN
10.0.0.0 - 10.255.255.255.255	255.0.0.0	1 class A LAN	16,777,216
172.16.0.0 - 172.31.255.255	255.255.0.0	16 class B LANs	65,536
192.168.0.0 - 192.168.255.255	25.255.255.0	256 class C LANs	256

3.1.2 Network and broadcast addresses

another important aspect of building a LAN is that the addresses at the two extreme ends of the address range are reserved for use as the LAN's network address and broadcast address. The network address is used by an application to represent the overall network. The broadcast address is used by an application to send the same message to all other hosts in the network simultaneously.For example, if you use addresses in the range of 192.168.1.0 to 192.168.1.128, the first address (192.168.1.0) is reserved as the network address, and the last address (192.168.1.128) is reserved as the broadcast address. Therefore, you only assign individual computers on the LAN IP addresses in the range of 192.168.1.1 to 192.168.1.127:

Table 33.2: *IP range for individual computers:*

Network address	192.168.1.0
Individual hosts	192.168.1.1 to 192.168.1.127
Broadcast address	192.168.1.128

3.1.3Subnet masks

Each host in a LAN has a subnet mask. The *subnet mask* is an octet that uses the number 255 to represent the network address portion of the IP address and a zero to identify the host portion of the address. For example, the subnet mask 255.255.255.0 is used by each host to determine which LAN or class it belongs to. The zero at the end of the subnet mask represents a unique host within that network**.**

3.1.4 Domain name

The domain name, or network name, is a unique name followed by a standard Internet suffixes such as .com, .org, .mil, .net, etc. You can pretty much name your LAN anything if it has a simple dial-up connection and your LAN is not a server providing some type of service to other hosts directly. In addition, our sample network is considered private since it uses IP addresses in the range of 192.168.1.x. Most importantly, the domain name of choice should not be accessible from the Internet if the above constraints are strictly enforced. Lastly, to obtain an "official" domain name you could register through Inter NIC, Network Solutions or Register.com.

3.1.5Hostnames

Another important step in setting up a LAN is assigning a unique hostname to each computer in the LAN. A hostname is simply a unique name that can be made up and is used to identify a unique computer in the LAN. Also, the name should not contain any blank spaces or punctuation. For example, the following are valid hostnames that could be assigned to each computer in a LAN consisting of 5 hosts: hostname 1 - Morpheus; hostname 2 - Trinity; hostname 3 - Tank; hostname 4 - Oracle; and hostname 5 - Dozer. Each of these hostnames conforms to the requirement that no blank spaces or punctuation marks are present. Use short hostnames to eliminate excessive typing, and choose a name that is easy to remember. Every host in the LAN will have the same network address, broadcast address, subnet mask, and domain name because those addresses identify the network in its entirety. Each computer in the LAN will have a hostname and IP address that uniquely identifies that particular host. The network address is 192.168.1.0, and the broadcast address is 192.168.1.128. Therefore, each host in the LAN must have an IP address between 192.168.1.1 to 192.168.127.

Table 3.3: *Sample IP addresses for a LAN with 127 or fewer interconnected computers*

IP address	Example	Same/unique
Network address	192.168.1.0	Same for all hosts
Domain name	Sust	Same for all hosts
Broadcast address	192.168.1.128	Same for all hosts
Subnet mask	255.255.255.0	Same for all hosts
Hostname	Any valid name	Unique to each host
Host addresses	192.168.1.*x*	*x* must be unique to each host

3.1.6 Assigning IP addresses in a LAN

There are two ways to assign IP addresses in a LAN. You can manually assign a *static* IP address to each computer in the LAN, or you can use a special type of server that automatically assigns a dynamic IP address to each computer as it logs into the network.

3.1.6.1 Static IP addressing

Static IP addressing means manually assigning a unique IP address to each computer in the LAN. The first three octets must be the same for each host, and the last digit must be a unique number for each host. In addition, a unique hostname will need to be assigned to each computer. Each host in the LAN will have the same network address (192.168.1.0), broadcast address (192.168.1.128), subnet mask (255.255.255.0), and domain name (yourcompanyname.com). It's a good idea to start by visiting each computer in the LAN and jotting down the hostname and IP address for future reference.

3.1.6.2 Dynamic IP addressing

Dynamic IP addressing is accomplished via a server or host called DHCP (Dynamic Host Configuration Program) that automatically assigns a unique IP address to each computer as it connects to the LAN. A similar service called BootP can also automatically assign unique IP addresses to each host in the network. The DHCP/ BootP service is a program or device that will act as a host with a unique IP address. An example of a DHCP device is a router that acts as an Ethernet hub (a communications device that allows multiple host to be connected via an Ethernet jack and a specific port) on one end and allows a connection to the Internet on the opposite end. Furthermore, the DHCP server will also assign the network and broadcast addresses. You will not be required to manually assign hostnames and domain names in a dynamic IP addressing scheme.

3.1.7 The LAN hardware

Assigning hostname and IP addresses will be useless if there is no hardware available to connect all the computers together. There are several different types of hardware schemes such as Ethernet, Token Ring, FDDI, Token Bus, etc. Since Ethernet is the most widely used hardware scheme, we will focus our attention on it. Ethernet is available from several different computer vendors, and it is relatively inexpensive. Ethernet is a 10-Mbps baseband LAN specification developed by Xerox, Intel, and Digital Equipment. In order to build an Ethernet hub you need the following: an Ethernet Network Interface Card (NIC) for each computer, an Ethernet compatible hub with at least the same number of ports as there will be computers in the LAN, and Ethernet cables (or 10BaseT cables) to connect each computer's NIC to the Ethernet hub.

Chapter four

4.1 Methodology

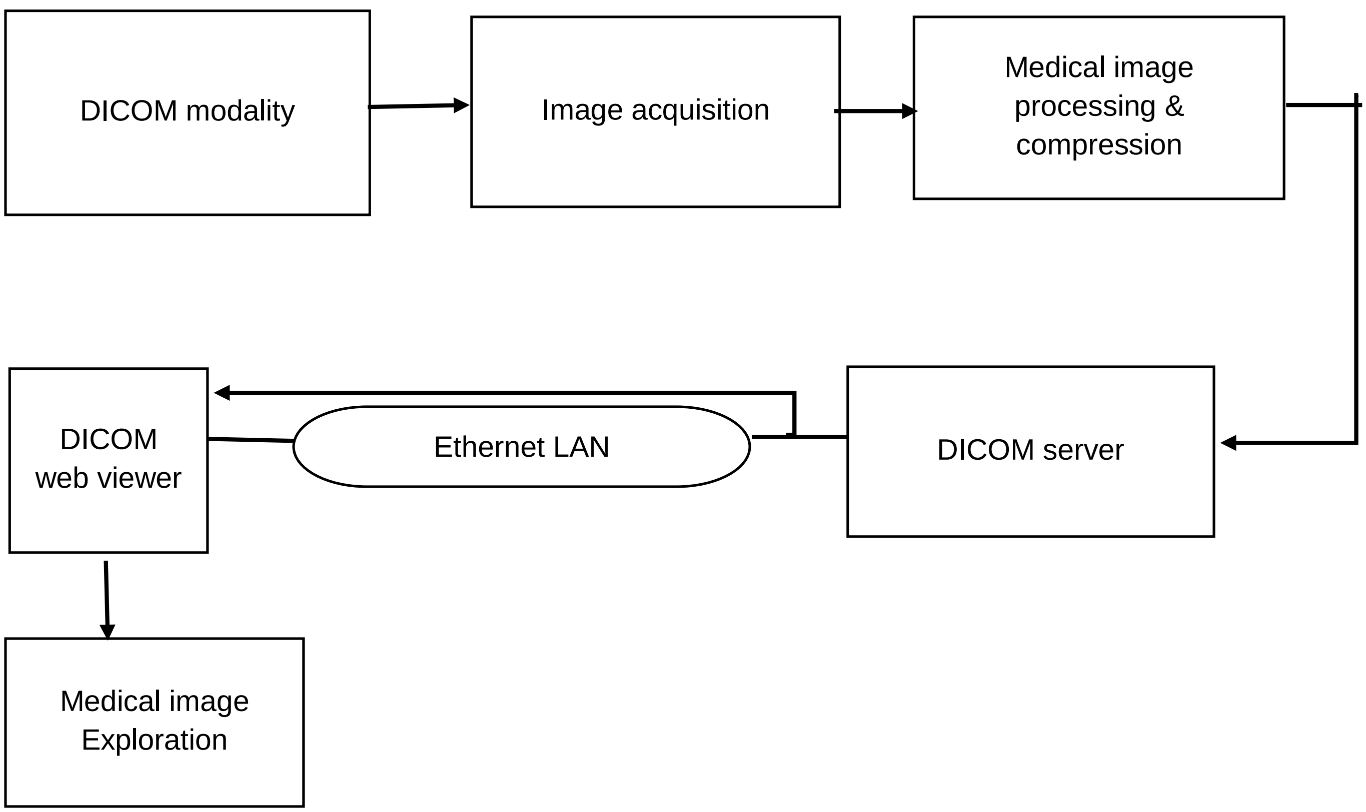


Figure 4.1 *web based medical image exploration*

4.1.1 web application

The quality of digital image has been deemed as an acceptable alternative to analog images for clinical, research, and teaching purposes if an enough information is retained in the digital image. [19] Online teaching files are an important source of educational and referential materials in the radiology community and are widely used.

The World Wide Web (WWW) is a great platform for distributing multimedia teaching files. Whereas DICOM is the standard of medical image format, it is not practical to distribute teaching files in DICOM format on the Internet because it takes too much time to transfer bulky medical image files through the Internet than with other compressed image file formats. To display DICOM files in general Web browsers, such as Internet Explorer or Mozilla, it requires an additional DICOM plug-in. Distributing teaching files in a hospital-wide PACS limits the accessibility because a secure private network cannot be accessed worldwide publicly building a dynamic Web site involves hypertext markup language (HTML) construction and frequent subsequent updates. Editing the HTML documents can be performed directly with simple text editing software or using dedicated Web publishing software. However, it often takes much effort and time when frequent updates are to be made. Using dynamic Web documents is a better approach when frequent updates are anticipated. The Common Gateway Interface (CGI) and server-side HTML-embedded scripting language is two of the most popular methods to produce dynamic HTML documents. There are many Web applications that allow radiologists to create teaching file collections through their Web browsers using dynamic Web document techniques. [20], [21], [22], [19] because most Web browsers support Joint Photographic Experts Group (JPEG)/Portable Network Graphics (PNG)/Graphics Interchange Format (GIF) image formats natively, these formats are used as the default.

With the widespread installation of PACS, DICOM is the most common file format radiologists use in daily practice. If a radiologist wants to upload teaching files to the Web server, he must convert files from DICOM into common Internet image formats (JPEG/PNG/GIF) first and then key in the clinical information.

This system was built with FreeBSD, [23] an advanced operating system for multiple architectures. FreeBSD is an open-source project and is extremely robust and powers some of the largest Internet sites in the world including Yahoo!, the Internet Movie Database, and Walnut Creek CDROM. We installed Apache [24]

a secure, efficient, and extensible open-source Web server. Apache is now the most popular Web server in the world. The SSL module encryption [25] was introduced to provide strong cryptography for the Apache 1.3 Web server via the Secure Sockets Layer (SSL v2/v3) and Transport Layer Security (TLS v1) protocols with the help of the Open-Source SSL/TLS toolkit. With strong encryption of the data stream, confidential information is protected.

The dynamic page content is produced by Hypertext Preprocessor (PHP), a widely used general-purpose HTML-embedded scripting language, the relational database is PostgreSQL, an Image Magick is a robust collection of tools and libraries offered under a usage license to read, write, and manipulate an image in many image formats, including the ability to convert DICOM files. The structure of our design is illustrated in Figure 1

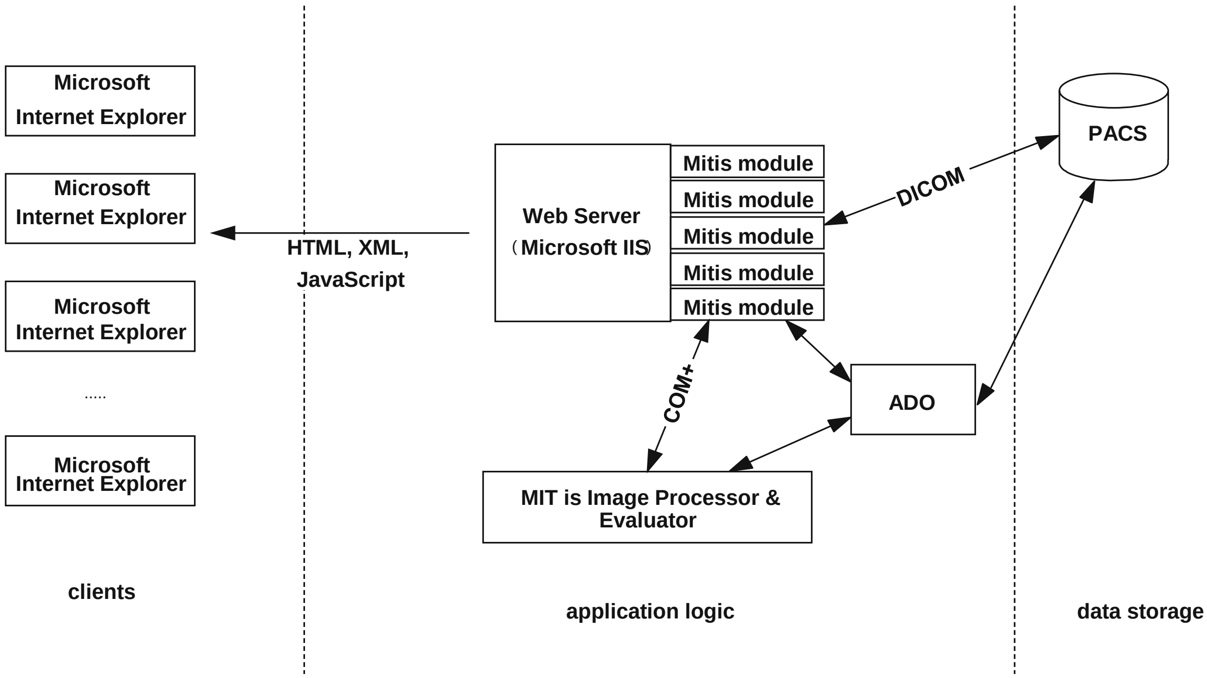


Figure 4.2 client server

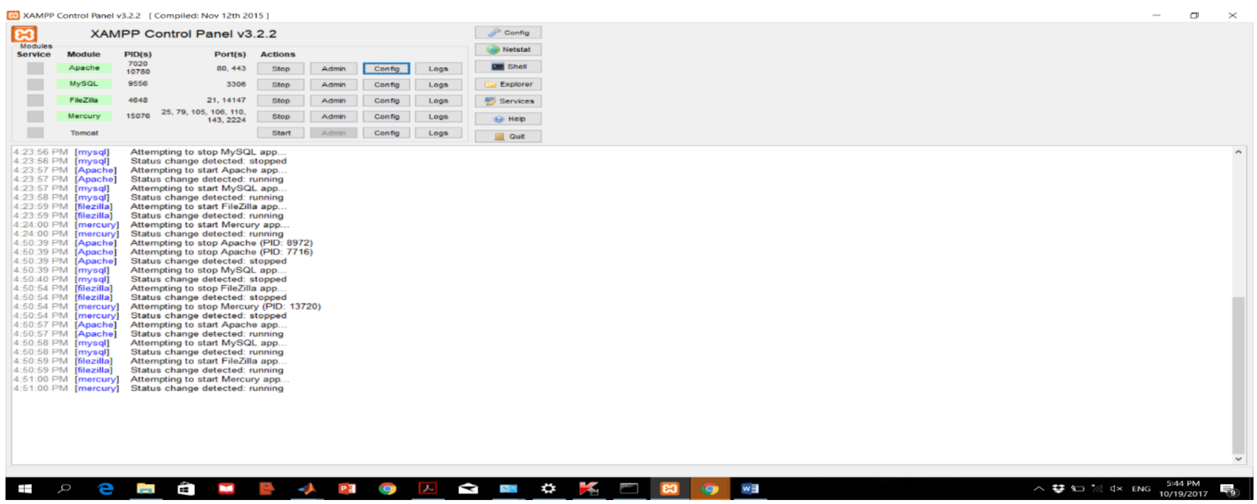
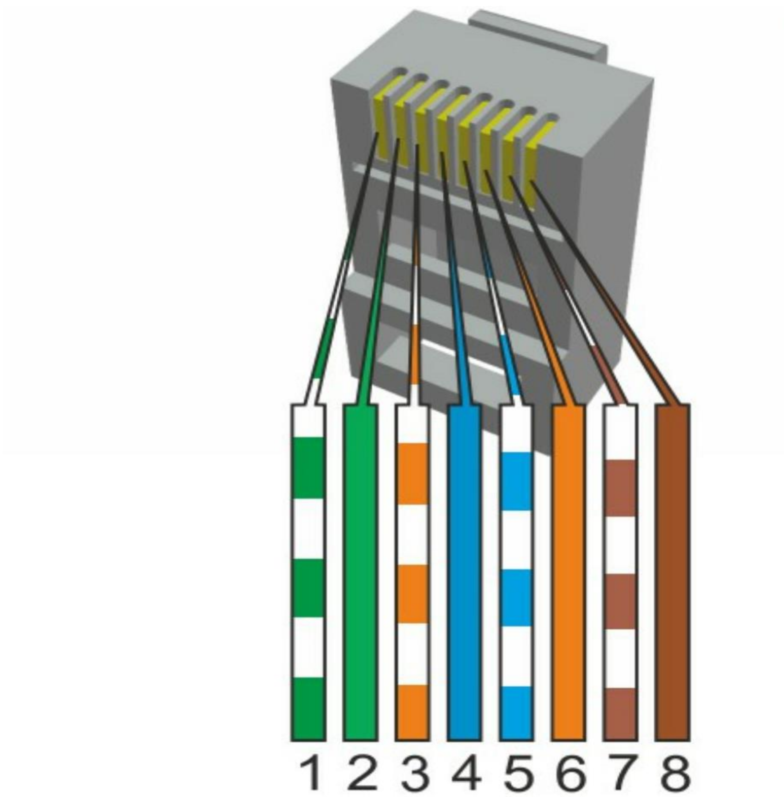


Figure 4.3 XAMPP control panel

4.2 NETWORK

4.2.1 LAN Hardware

Obtain network crossover cable ;this type of ethernet cable use for conecting two computers (RJ-45)



Pin	Description	10base-T	100Base-T	1000Base-T
1	Transmit Data+ or BiDirectional	TX+	TX+	BI_DA+
2	Transmit Data- or BiDirectional	TX-	TX-	BI_DA-
3	Receive Data+ or BiDirectional	RX+	RX+	BI_DB+
4	Not connected or BiDirectional	n/c	n/c	BI_DC+
5	Not connected or BiDirectional	n/c	n/c	BI_DC-
6	Receive Data- or BiDirectional	RX-	RX-	BI_DB-
7	Not connected or BiDirectional	n/c	n/c	BI_DD+
8	Not connected or BiDirectional	n/c	n/c	BI_DD-

Figure 4.4 RJ-45 Wiring daigram and cable diagram

Obtain sattic IPAdress(TCP/IP)

For PC1:

IP Adress: 192.168.0.2

Subnet mask:255.255.255.0

Default gateway:do not enter in a value

For PC2:

IP Adress: 192.168.0.3

Subnet mask:255.255.255.0

Default gateway:do not enter in a value

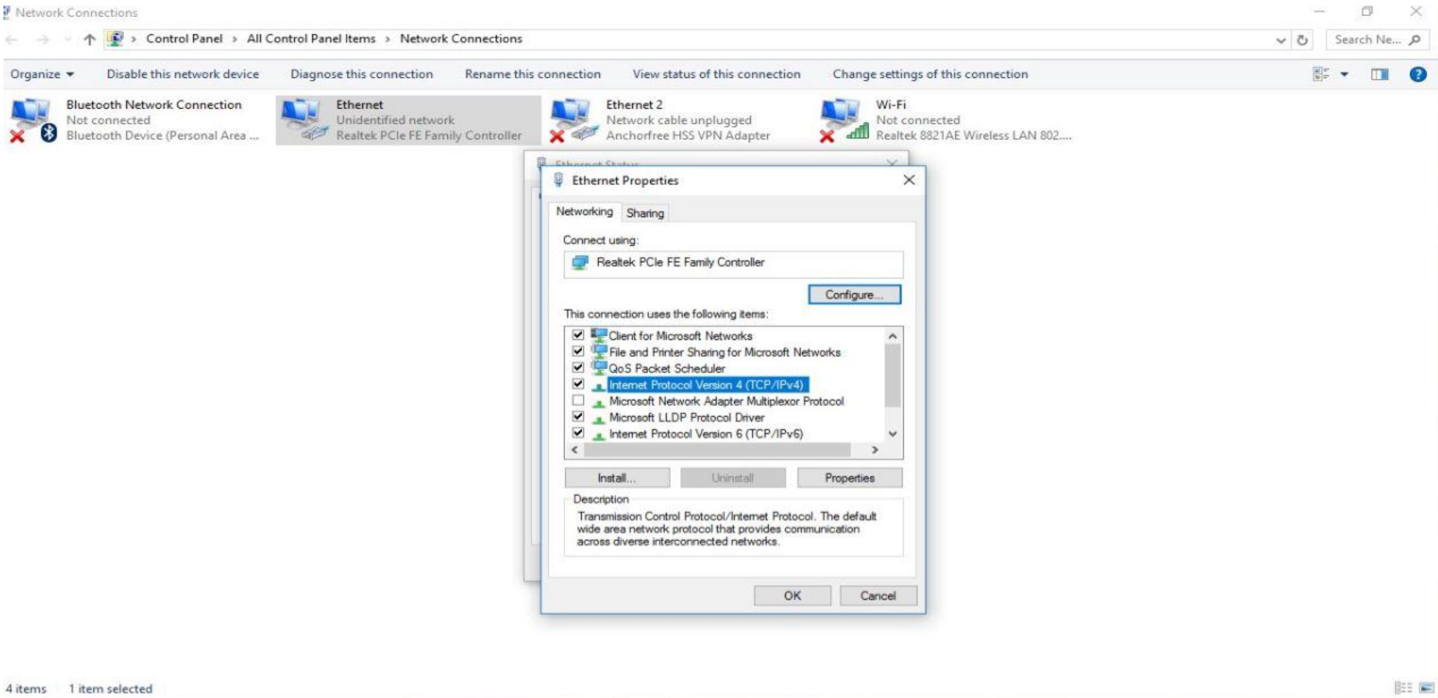


Figure 4.5: Internet Protocol Version (TCP/IPv4) For PC1

Using Internet Protocol Version (TCP/IPv4) for making conection between the two laptop on the same sub-network

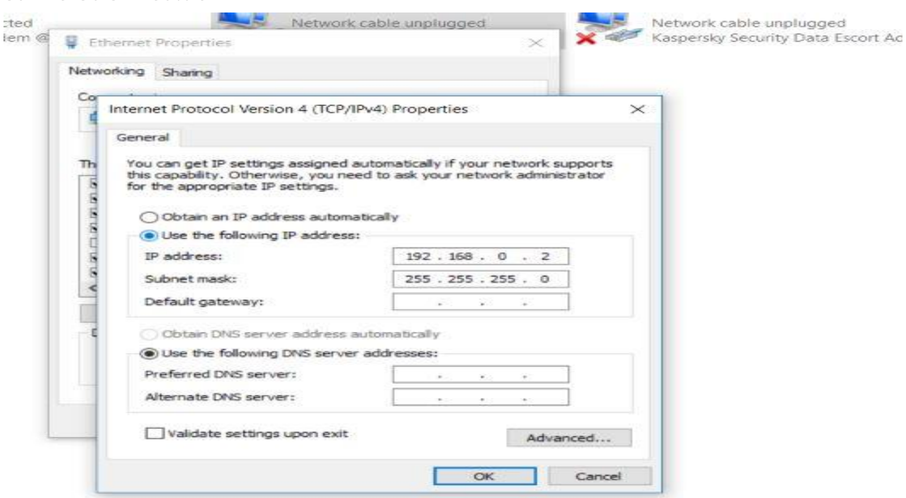


Figure 4.6: Obtain Static IPv4 For PC1

IP Adress: 192.168.0.2

Subnet mask:255.255.255.0

Default gateway:do not enter in a value

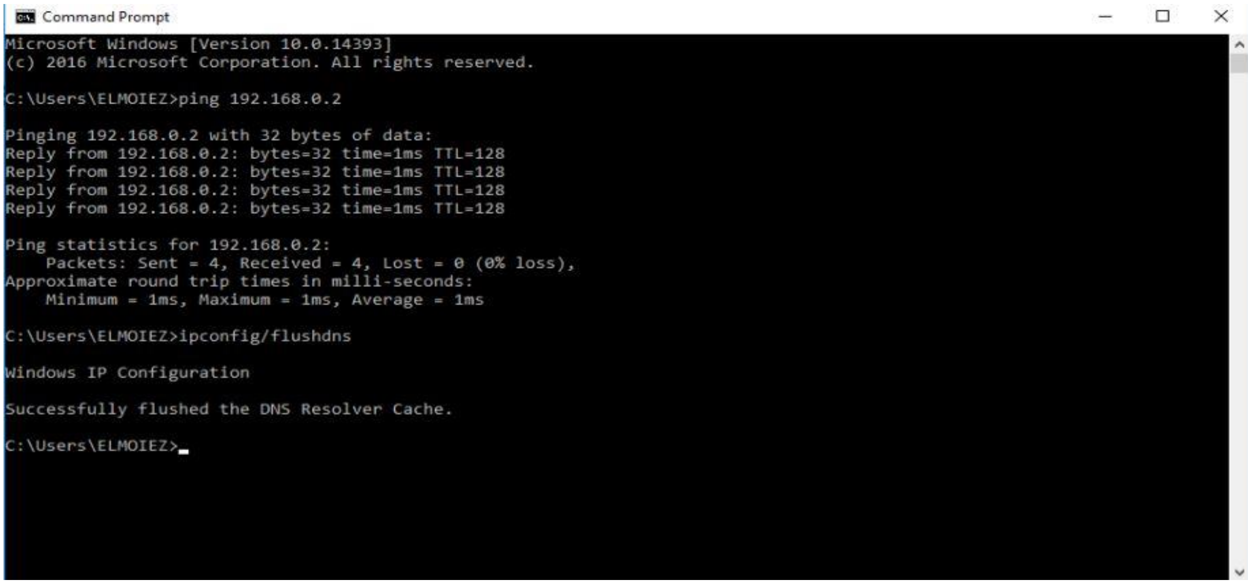


Figure 4.7: IP Configuration & flushdns for PC1

Open command port on the PC2 for ensure that there was replay from pc1 by using the command > Ping 192.168.0.2

Then using the command > Ipconfig/flushdns for successfully flushed the DNS resolve cache

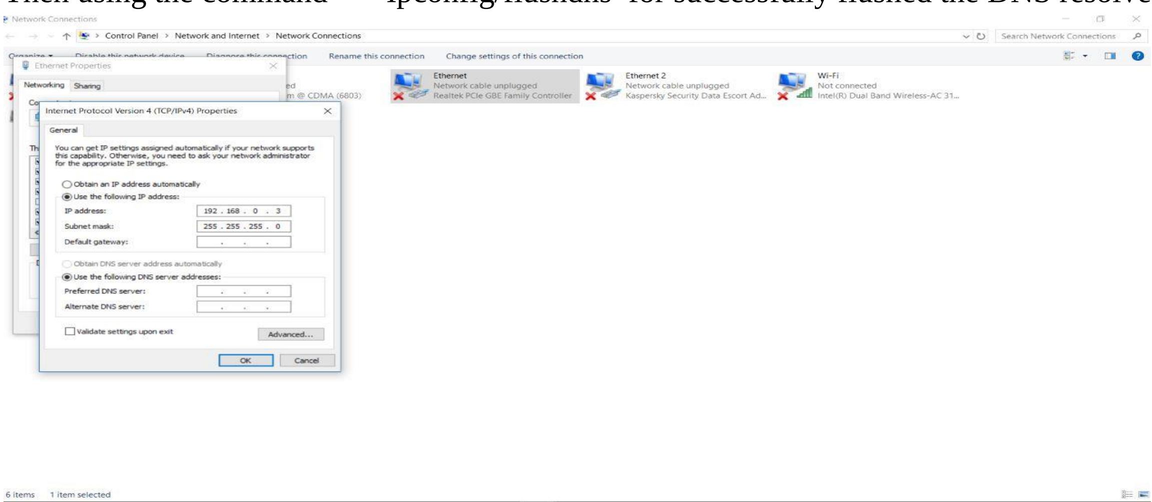


Figure 4.8: Obtain Static IPv4 For PC2

IP Adress: 192.168.0.3

Subnet mask:255.255.255.0

Default gateway:do not enter in a value

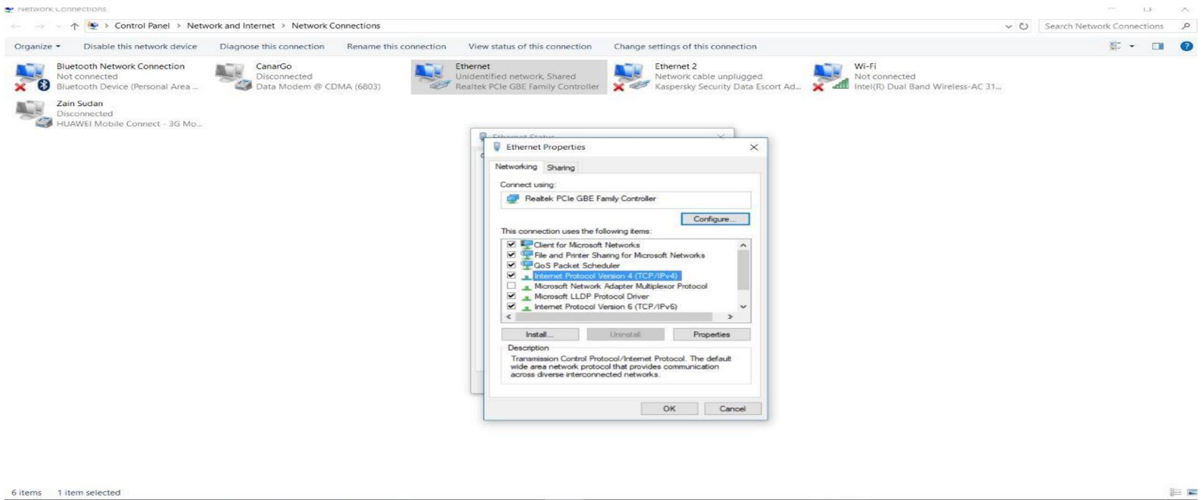


Figure 4.9: Internet Protocol Version (TCP/IPv4) For PC2

Using Internet Protocol Version (TCP/IPv4) for making conection between the two laptop on the same sub-network

Figure 4.10 IP Configuration & flushdns for PC2

Open command port on the PC1 for ensure that there was replay from pc2 by using the command > Ping 192.168.0.3

Then using the command > Ipconfig/flushdns for successfully flushed the DNS resolve cache

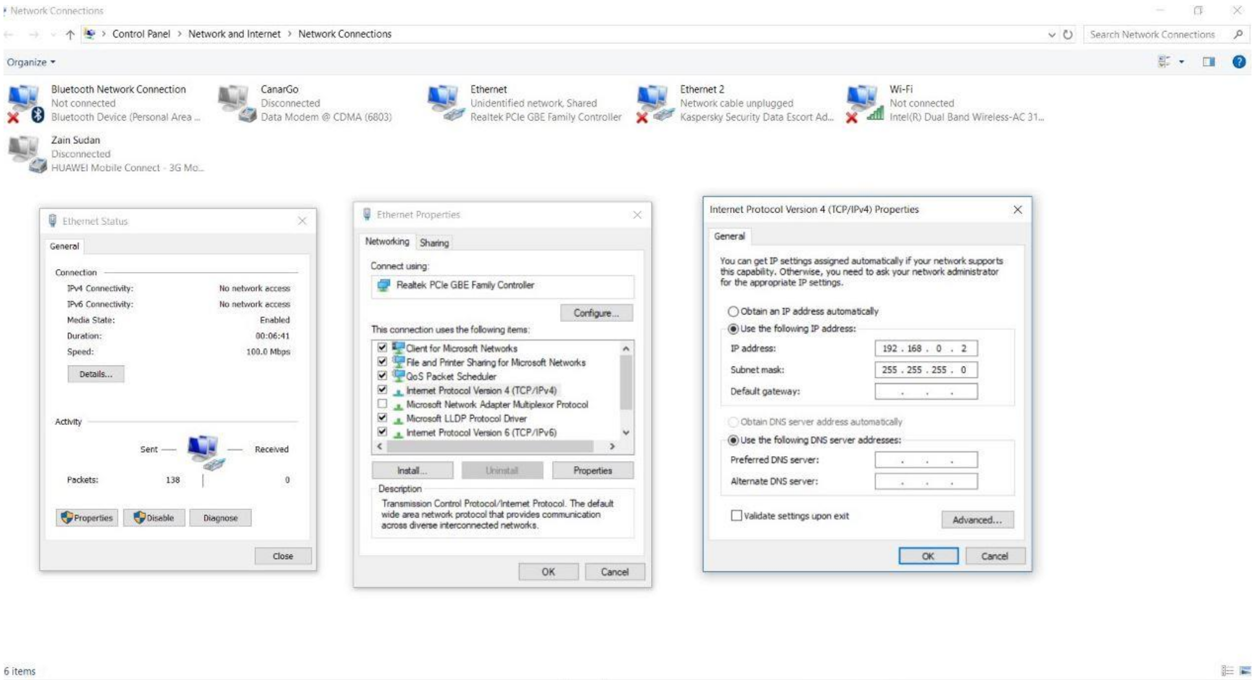


Figure 4.11: General block diagram for establish LAN between two laptops

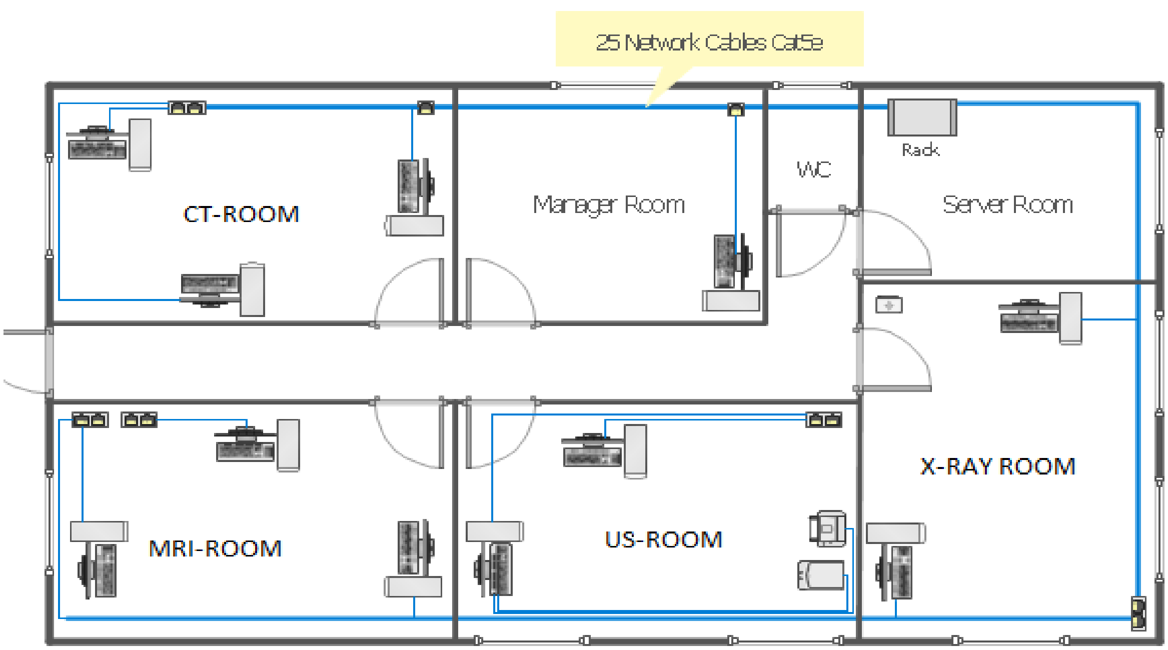


Figure 4.12local area network on small radiology department

4.3 Image compression and processing

To reduce the redundancy and irrelevancy presented in the image, so that it could be stored and transferred efficiently We used Image compression for reducing the amount of data needed to represent medical image. Medical image contains a lot of information which brings difficulties of storage, processing and transmission. Thus, image compression was a necessary step.

Image compression have two types, lossless and lossy compression. In lossless compression the reconstructed image, after compression, is numerically identical to the original image. However lossless compression can only achieve a modest amount of compression. Lossless compression is preferred for archival purposes and often medical imaging because lossy compression methods, especially when used at low bit rates, introduce compression artifacts. An image reconstructed following lossy compression contains degradation relative to the original. Often this is because the compression scheme completely discards redundant information. However, lossy schemes can achieve much higher compression.

We chose DCT firstly for the compression. The DCT work by separating images into the parts of different frequencies. During a step called Quantization, where parts of compression occur, the less important frequencies are discarded, hence the use of the lossy. Then the most important frequencies that remain are used retrieve the image in decomposition process.

In DCT algorithm we divided the input image into 8 by 8 blocks, computed two-dimensional DCT for each block.

If represents a 2D image of size x (n1, n2) N × N, the 2D DCT of image is given by:

$$Y[j,k]=\sum_{m=0}^{n-1}\sum_{n=0}^{n-1} C[j]C[k]y[j,k]\cos\left(\frac{(2m+1)j\pi}{2N}\right)\cos\left(\frac{(2n+1)k\pi}{2N}\right) \quad \textbf{(1)}$$

Where j, k, m, n=0,1, 2…., N-1 and

$$C[j] \text{ and } C[k] = \begin{bmatrix} \sqrt{\frac{1}{N}} & if_{J,k=0} \\ \sqrt{\frac{2}{N}} & if_{j,k>0} \end{bmatrix}$$

We quantized DCT coefficients then coded, and transmitted. The receiver decoded the quantized DCT coefficients.
computed the inverse two-dimensional DCT (IDCT) of each block. By:

$$X\,[m,n] = C[j]C[k]\sum_{m=0}^{n-1}\sum_{n=0}^{n-1} x[m,n]\cos\left(\frac{(2m+1)j\pi}{2N}\right)\cos\left(\frac{(2n+1)k\pi}{2N}\right) \quad \textbf{(2)}$$

finally, put the blocks back together into a single image.

DCT had advantages such as simplicity, satisfactory performance, and availability of special purpose hardware for implementation. However, there was one major disadvantage of the DCT, While the input from preprocessed 8x8 blocks were integer-valued, the output values were typically real-valued. Thus, we needed a quantization step to make some decisions about the values in each DCT block and produce output that is integer-valued. The DCT compression code implemented using MATLAB

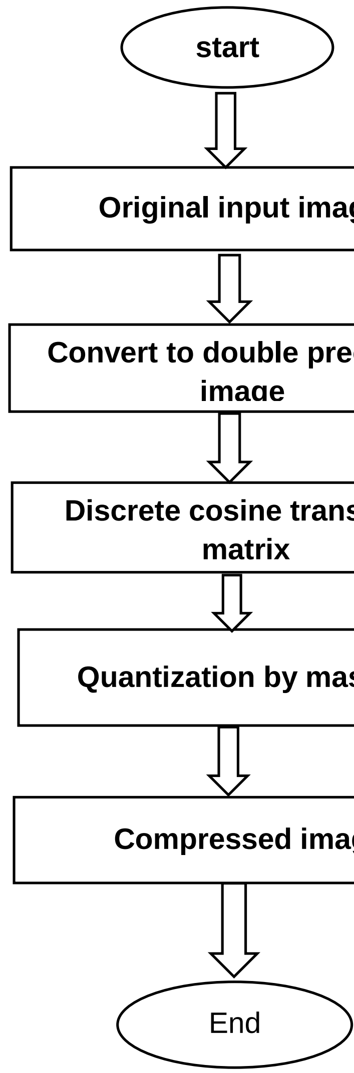


Figure 4.13 Discription of DCT code

The input image was blocked, correlation across the block boundaries could not be eliminated. This resulted in noticeable and annoying "blocking artifacts"' particularly at low bit rates. Because of this reason we chose discrete wavelet transform for lossless image compression. The fundamental idea behind wavelets is to analyze the signal at different scales or resolutions.

Wavelets are mathematical functions that can be used to transform one function representation into another.

Wavelet transform performed multiresolution image analysis. Multiresolution means simultaneous representation of image on different resolution levels. Wavelet transform represented an image as a sum of wavelets functions, with different location and scales. The 2D wavelet analysis used the same „mother wavelets" but required an extra step at every level of decomposition. We also used MATLAB for the DWT code. wavelet transform' decomposes image signals based on scale or resolution, rather than the frequency content based decomposition resulting from the discrete cosine transform used in today's JPEG algorithm.

The signal is decomposed into a lower resolution signal together with a detail signal and is calculated using:

- Low-Pass filter both image rows and columns
- Low-pass filter image rows and High pass filter image columns
- High-pass filter image rows and low pass filter image columns
- High-pass filter both image rows and columns

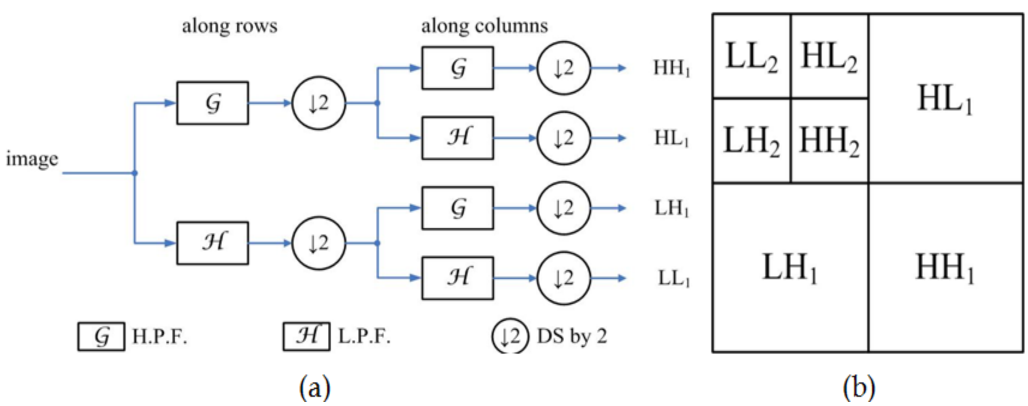


Figure 4.14 *description of decomposition level process* **(***a) wavelet process (b)decomposition level*

The process repeated recursively on the low-resolution image to create a series of reduced resolution images, also referred to as sub bands. increasing the number of wavelet decomposition levels, the low-low sub band is further decor-related. However, the incremental benefits resulting from successive wavelet decomposition are diminished beyond some practical limit that is primarily driven by the number of pixels in the original image

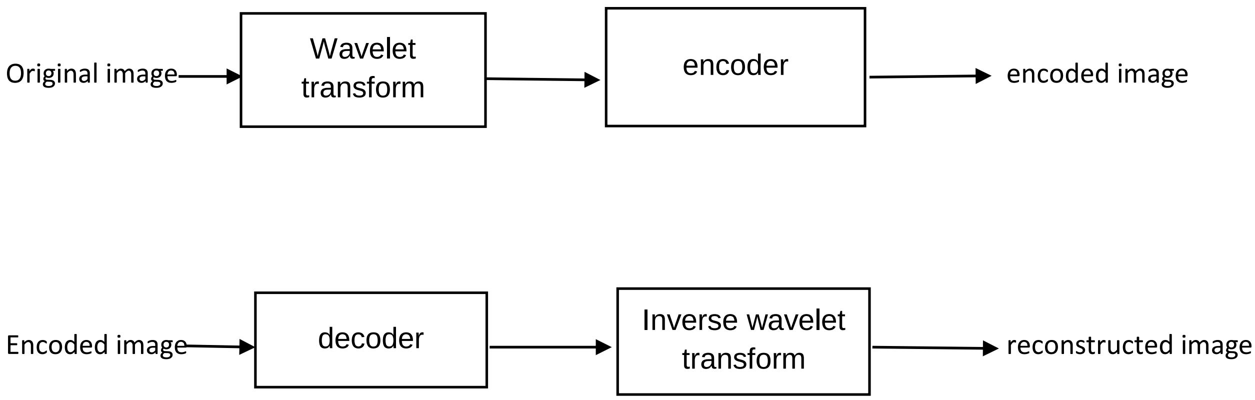


Figure 4.15 Description of DWT code

1.**Digitation*****:*** The image is digitized first. The digitized image can be characterized by its intensity levels, or scales of gray which range from 0(black) to 255(white), and its resolution, or how many pixels per square inch.

2. **Thresholding*****:*** In certain signals, many of the wavelet coefficients are close or equal to zero. Through threshold these coefficients are modified so that the sequence of wavelet coefficients contains long strings of zeros. In hard threshold, a threshold is selected. Any wavelet whose absolute value falls below the tolerance is set to zero with the goal to introduce many zeros without losing a great amount of detail.

3. **Quantization*****:*** Quantization converts a sequence of floating numbers w' to a sequence of integers q. The simplest form is to round to the nearest integer. Another method is to multiply each number in w' by a constant k, and then round to the nearest integer. Quantization is called lossy because it introduces error into the process, since the conversion of w' to q is not one to one function.

4. **Entropy encoding*****:*** With this method, an integer sequence q is changed into a shorter sequence with the numbers in e being 8-bit integers. The conversion is made by an entropy encoding table. Strings of zeros are coded by numbers 1 through 100,105 and 106, while the non-zero integers in q are coded by 101 through 104 and 107 through 254.

The principle objective of image enhancement technique is to process an image
so that the resultant image is more suitable than the original for application.

We used some of the error metrics to compare the image compression techniques the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) to achieve desirable compression ratios. The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction.

compression ratio, also known as compression power, is used to quantify the reduction in data-representation size produced by data compression. The data compression ratio is analogous to the physical compression ratio it is used to measure physical compression of substances, and is defined in the same way, as the ratio between the uncompressed size and the compressed size.

Mean square error is a criterion for an estimator: the choice is the one that minimizes the sum of squared errors due to bias and due to variance. The average of the square of the difference between the desired response and the actual system output.

$$\text{MSE}=\frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2 \qquad \textbf{(3)}$$

where, I (x, y) is the pixel in the input image,

I’ (x, y) is the pixel in the reconstructed image,

M × N is the size of input image.

Peak signal to noise ratio (PSNR) It is the ratio between the maximum possible power of a signal and the power of corrupting noise.

$$\textbf{PSNR} = \mathbf{20 * \log 10\left(\frac{255}{\sqrt{MSE}}\right)} \qquad \textbf{(4)}$$

Chapter five

Results

5.1 DICOM web viewer

This section provides a technical description of our developed DICOM Web Viewer in details. Additionally, we present screenshots of our application.

To make our application easy to use for a broad audience, following requirements were identified:

1. Load and display DICOM images by specifying a directory.
2. Sort images by patient's name and study's name.
3. Scrolling through the images of a series.
4. Changing the windowing function.
5. Zooming.
6. Length measurement.
7. Show patient and study information in the corners.
8. Display all DICOM attributes of the image.
9. Reset functionality

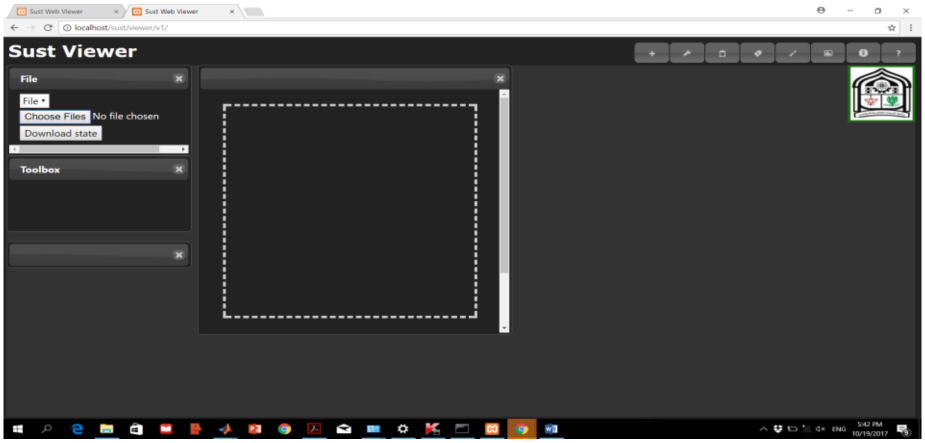


Figure 5.1*Web based DICOM viewer*

5.1.1 User Interface:

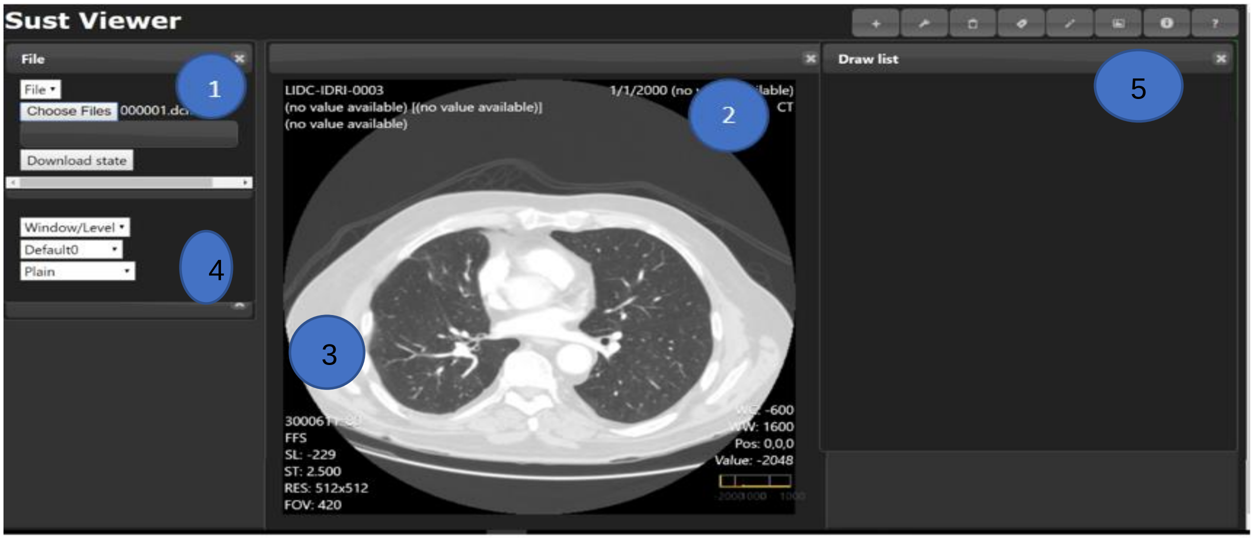


Figure5.2 User interface

(1) file input, (2) important information displayed in the corners, (3) actual image, (4) toolbox, (5) Toolbar

(1) input image: options of choose file or download state use to select an image for study, the selected image will be display at the viewer.

(2) important information displayed in the corners: shown the current window width(WC), the window width(WW), the date and time, the patient name, sex and patient's ID, field of view, resolution, image modality

(3) the selected image.

(4) toolbar: History, DICOM tags, Annotations, Image, Information, Help.

(5) toolbox

5.1.2 Toolbox options:

their functionalities description:

- Window Level: By selecting this functionality, the parameters of the windowing function - window center and window width - can be altered. Therefor the user moves the mouse pointer to the image, presses and holds down the left button of the mouse, moves the pointer along the x-axis or y-axis and releases the button at the end. “Dragging” along the x-axis changes the value of the window center, along the y-axis the value of the window width. Illustrates the effect of changes in window center- and window width-values on the same image.

- Zoom: When this functionality is activated, the user can zoom in or out of the image by drag and-drop.
- Draw: When this functionality is activated, the user can put marks (arrow, ruler, protractor, rectangle, roi, ellipse, free hand) on the image during his diagnosis.
- Livewire: to find the path line between the fixed start point and the variable endpoint.
- Filter: there are three filters (threshold, sharpen and sobel filters) use for enhancing the image and remove noise.
- Flood fill: this option applied on an image to fill a bounded area with color.
- Default0: provide display options like (min/max, mediastinum, lung, brain, head, bone).
- Plain: when this functionality activated it provide color calibration display for the image by this method (Invplain, Rainbow, Hot, Hot iron, Pet, Hot metal blue and Pet 20 steps) to help the user in diagnosis.

5.2 Compression of Wavelet transform result:

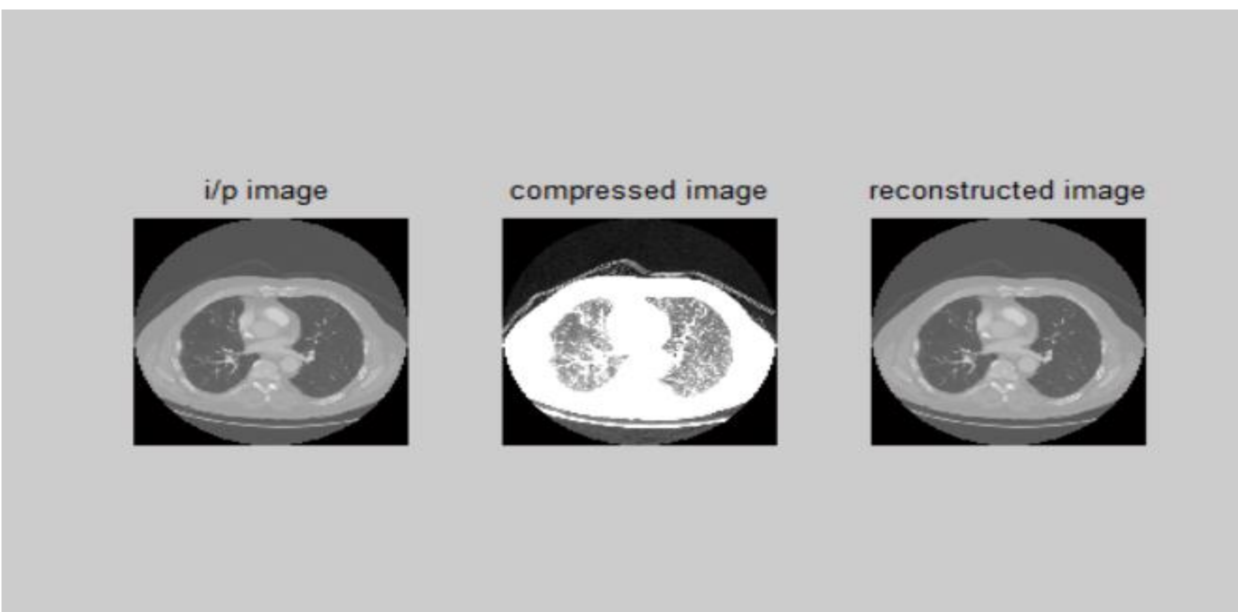


Figure 5.3**:** shown the input original image, the compressed image, the reconstruct image

__table 5.1:__ comparison between size before and after compression

Image	Size before compression	Size after compression
Image 1	524k bytes	48 bytes
Image 2	627k bytes	51 bytes
Image 3	165k bytes	48 bytes

This table describes the size of medical image before compression process and the size of same images after compression.

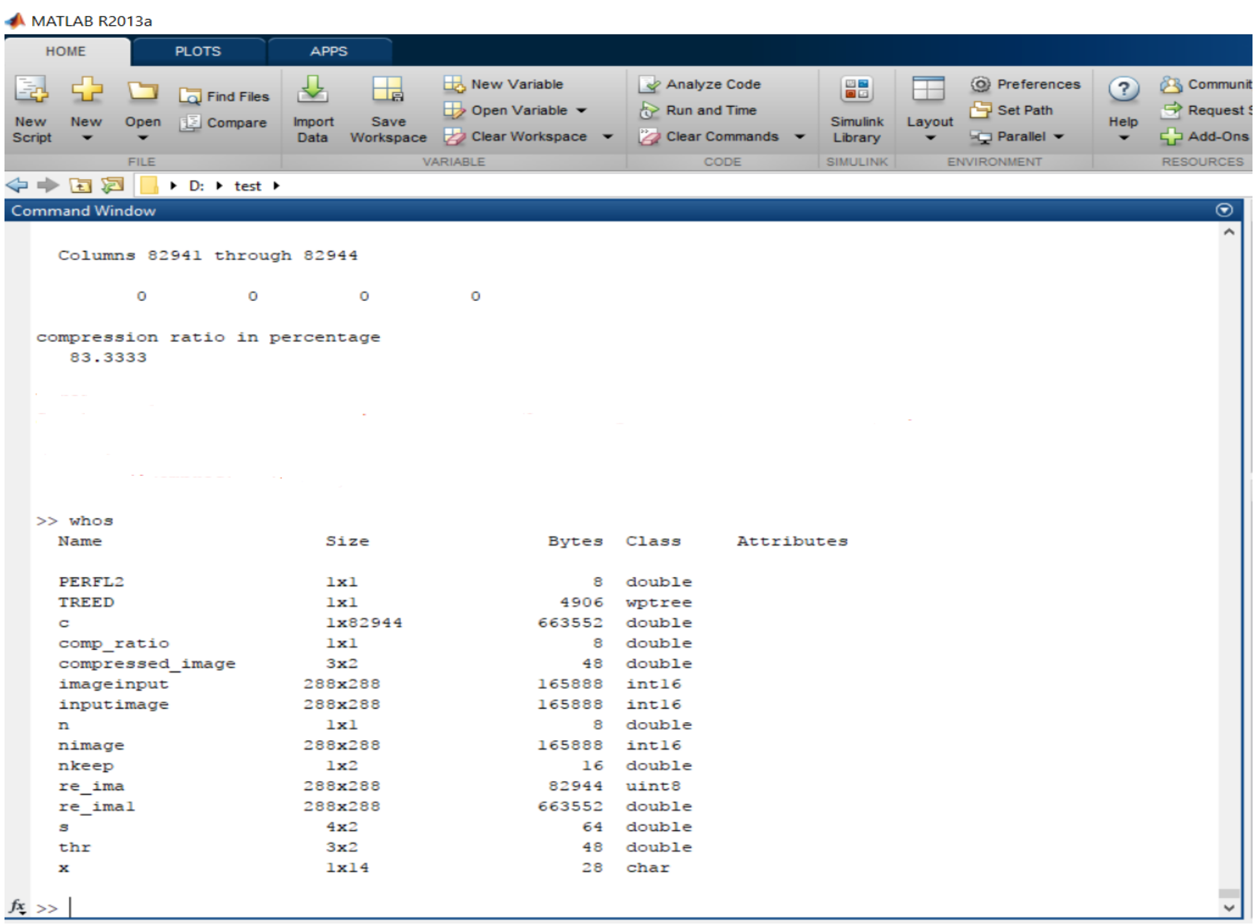


Figure 5.4 image size before and after compression for image number represented on table

Table 5.2: *CR, MSR, PSNR of wavelet transform at decomposition level 2*

WEVELET FILTER	COMPRESSION RATIO	MSR	PSNR
Db1	83.33	1.51	296.6
Db4	82.88	1.30	2.94
Coif1	83.86	2.22	4.76
Coif5	80.12	2.13	5.16
Dmey	71.96	2.42	4.28
Sym2	83.39	4.54	1.55
Sym8	81.62	2.94	3.43
Sym25	77.00	8.91	8.61
Bior1.1	83.3	1.52	296.26
Bior2.2	83.1	3.05	3.28
Bior4.4	82.98	1.20	403.61
Bior6.8	81.78	2.42	4.26
Rbio1.1	83.5	1.56	296.27

This table describes different types of wavelet filters used and CR, MSR, and PSNR for each filter.

5.3 Discussion

DICOM services are used for communication of imaging information objects within a device and between devices.

the DICOM Web Viewer should be accessible from any modern web browser (Firefox, Chrome, Safari, Opera, Internet Explorer, etc.) within different operating systems and without the need to install external plugins.

The effects of different wavelet functions, filter orders, number of decompositions, image contents, and compression ratios are examined. The final choice of optimal wavelet in image compression application depends on image quality and computational complexity.

Increasing the decomposition level increasing the MSE and Compression Ratio and lower the PSNR, higher order filter shows the low compression ratio, low MSE with high PSNR

Wavelet based compression scheme can avoid blocking artifacts that is noticeable in DCT technique. Biorthogonal 4.4 wavelets are most suitable for medical image compression application.

Chapter six

Conclusion and Recommendations

6.1 Conclusion

This research describes implementation of dynamic web page for DICOM viewing and the detailed overview of viewer's user interface has been given. All functionalities of toolbox have been described using screenshot.

In teleradiology web based DICOM viewers are used to view medical images, however current solutions support only uncompressed DICOM files. Research highlighted the advantage of DICOM transmission for telemedicine applications by compressing DICOM images using wavelets transform coding which has much better coding efficiency and less computational complexity, wavelet algorithm implemented by MATLAB. The CR, MSR and PSNR were calculated in addition a description of the source code by flow chart and screenshot show the compressed a reconstructed image.

6.2 Recommendations

Future aspects related to connect DICOM viewer with wide area network (WAN) for remote access of data and allow transmission between different healthcare facilities.

Due to the sensitivity of medical image content, an encryption method should be investigated for more security and client's privacy.

Web page can be developed and used for educational purpose as medical image archive to be used for E-learning by medicine and radiology students

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Appendix

quantized DCT coefficients then coded, and transmitted. The receiver decoded the quantized DCT coefficients by this equation:

$$Y[j,k]=\sum_{m=0}^{n-1}\sum_{n=0}^{n-1} C[j]C[k]y[j,k]\cos\left(\frac{(2m+1)j\pi}{2N}\right)\cos\left(\frac{(2n+1)k\pi}{2N}\right) \quad \textbf{(1)}$$

Where j, k, m, n=0,1, 2…., N-1 and

$$C[j] \text{ and } C[k] = \begin{bmatrix} \sqrt{\frac{1}{N}} & if_{J,k=0} \\ \sqrt{\frac{2}{N}} & if_{j,k>0} \end{bmatrix}$$

computed the inverse two-dimensional DCT (IDCT) of each block By this equation:

$$X[m,n] = C[j]C[k]\sum_{m=0}^{n-1}\sum_{n=0}^{n-1} x[m,n]\cos\left(\frac{(2m+1)j\pi}{2N}\right)\cos\left(\frac{(2n+1)k\pi}{2N}\right) \quad \textbf{(2)}$$

Mean square error is a criterion for an estimator: the choice is the one that minimizes the sum of squared errors due to bias and due to variance. The average of the square of the difference between the desired response and the actual system output

$$MSE=\frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2 \quad \textbf{(3)}$$

where, I (x, y) is the pixel in the input image,

I’ (x, y) is the pixel in the reconstructed image,

M × N is the size of input image.

Peak signal to noise ratio (PSNR) It is the ratio between the maximum possible power of a signal and the power of corrupting noise.

$$\text{PSNR} = 20 * \log 10 \left(\frac{255}{\sqrt{MSE}}\right) \quad \textbf{(4)}$$