Implementation of a simulated Radiology DICOM–PACS network

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Abstract: - This paper presents the implementation of a laboratory classroom simulation of radiology networking technology. The simulation focuses on educating undergraduate students in various aspects of installing and applying radiology Picture Archiving and Communication Systems (PACS) in a networked environment, based on the Digital Image and Communication in Medicine (DICOM) standard, with particular emphasis placed on student-centered learning. Laboratory structure enables students to simulate the operation of radiology departments in terms of DICOM communication with imaging devices, storage and archiving of DICOM information and DICOM-compatible digitization of film-printed radiographs.

Key Words: - DICOM, PACS, Biomedical engineering education, student-centered learning

1 Introduction *

Picture Archiving and Communication Systems (PACS) have become necessary for storing, printing, retrieving and reviewing in an efficient manner the high volumes of data extracted from imaging devices, i.e. modalities, such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Digital Radiography (DR) etc. [1, 2]. The Digital Imaging and Communications in Medicine (DICOM) standard has been universally accepted by the medical industry for exchanging imaging data between modalities [3].

Although DICOM-PACS technology is well established in many radiology departments, it is difficult for Universities to access it without securing cooperation with hospitals that implement such technology. Even when such cooperation is established, finding a "time slot" in the radiology department's operation and educating in-depth students on systems that are in operation is difficult and raises ethical questions since real patient data are stored and processed.

The DICOM-PACS laboratory implementation presented in this work simulates the networked operation of radiology departments eliminating the need to purchase expensive DICOM medical devices. Furthermore it provides detailed education to undergraduate students based on the learner–centered education model [4].

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2 Implementation methodology

2.1 DICOM–PACS overview

DICOM has emerged in the 1980's by a joint effort of the American College of Radiologists (ACR) and the National Electrical Manufacturers Association (NEMA) [3]. It is becoming trivial for Medical Diagnostic Imaging devices such as computed tomography (CT), magnetic resonance (MR) imaging, Ultrasonography (US), nuclear medicine, fluroscopy and digital radiography to retrieve and process medical images in digital format. ACR-NEMA standard enables equipment of different manufacturers and modalities (CT, MR, etc) to communicate medical images and relevant information. DICOM standard represents the format and protocol in which digital radiology devices and scanners must use to facilitate interoperability. It specifies the syntax, semantics of Commands and associated information which can be exchanged with the use of these protocols; medical directory structures and file format for media storage devices – systems [3]. DICOM enabled devices require special software and viewers in order to receive and send DICOM information. DICOM works in a networked environment using industry-standard TCP/IP and enables digital medical image transfer containing relevant equipment, patient and medical data. Medical devices that conform to the latest DICOM protocol are capable of exchanging information over the network. Current DICOM standard is DICOM 3.

DICOM files are usually quite large, thus TCP/IP technical characteristics should be considered prior to installing a DICOM network. Usually transfer of DICOM files is done uncompressed or with compression algorithms that do not alter the file data while decreasing the image size.

Current trends in DICOM technology include Web enabled devices that could transmit and receive DICOM files over the internet. However security and band width of internet is an issue under discussion.

PACS utilizes DICOM to exchange information with imaging modalities. PACS systems act both as medical image diagnostic viewer systems, enabling commenting, zooming, trimming and other image processing functions, and as storing and archiving systems [1]. PACS have built-in databases that support the storage/archiving functions and are usually equipped with both short and long-term storage devices such as Hard Disks and optical compact disks juke boxes.

Since printing and digitizing analog films is important for radiology departments, PACS can communicate with DICOM-compliant printers and scanners. Furthermore, in an advanced radiology department PACS provide connectivity with health information systems, such as Radiology Information Systems (RIS) ,Hospital Information Systems (HIS) and HL7.

Full featured PACS solutions have also embedded characteristics such as domain – network security with different access levels, department and systems schedulers, report managers and post processing workflow profiles.

2.2 DICOM–PACS laboratory structure

The laboratory is structured on networked PCs equipped with TCP/IP, running Microsoft Windows 2000™ operating system; each of them hosting a DICOM- compatible software tool. The structure is such as to "mimic" a radiology department.

Two computers on the network are equipped with DICOM imaging and gateway software and represent the modalities (Fig.1). DICOM modalities software technical characteristics include:

- Displaying of diagnostic quality medical images.
- Image processing such as windowing, trimming, rotation, positive/negative imaging, digital filters application on images and postproccesing.
- Storage application of DICOM Storage Service Class User (SCU), which enables sending DICOM images to DICOM Storage Service Providers (SCP).
- Query/Retrieve application, which enables sending and move/get requests to DICOM Query/Retrieve SCP.
- Print application, implements DICOM Basic Print User (SCU) which sends DICOM files to Print Providers.
- Worklist, implementing DICOM Modality Worklist SCU, which sends worklist queries to SCP.
- File storage, implements storage of selected DICOM files to file storage medium.

One computer, the "PACS PC", is assigned with server (workstation) capabilities and has installed miniPACS software. The workstation is equipped with dual flat screens in order to act also as a medical diagnostic viewing station, and CD/DVD storage devices for storing and archiving. The software installed on the workstation, is a DICOM server that accepts and transfers data to and from modalities. The software has built-in database capabilities for short and long-term storage and archiving.

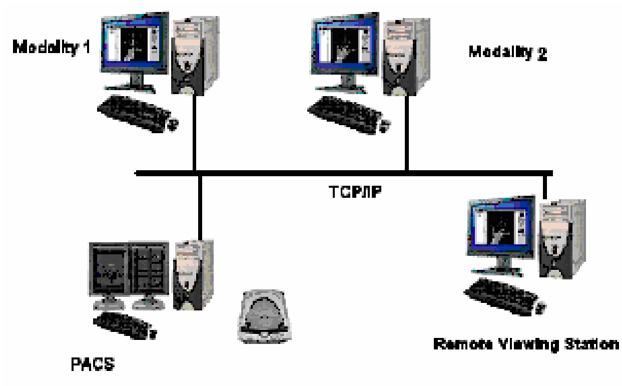

Fig. 1: Laboratory DICOM-PACS structure

The PACS PC is also equipped with scanning software that enables it to communicate with DICOM-compatible film scanners. The software "translates" the digitized film-printed images into DICOM-compatible files.

The PACS workstation main technical characteristics are:

- Displaying of diagnostic quality medical images.
- Image processing such as windowing, trimming, rotation, positive/negative imaging, digital filters application on images, postproccesing, annotation, and multiple image viewing.
- Query/Retrieve application, which enables sending and move/get requests to DICOM Query/Retrieve SCP.
- Print application, implements DICOM Basic Print User (SCU) which sends DICOM files to Print Providers.
- Worklist, implementing DICOM Modality Worklist SCU.
- Multiplanar reconstruction of CT & MRI DICOM images, allowing real time reconstruction in any plane and viewing multiple slices at a time.
- Multiple users' access enables creation of user profiles with different logs on the same workstation.
- Long Term Media Storage, embedded feature for allowing directly storage of DICOM files to CD's from the software.
- Volume rendering, feature that enables 3D viewing of DICOM reconstructed files.
- DICOM printing, feature that conforms DICOM print to a variety of DICOM printer manufacturers.
- Scanning, feature that enables the acquisition of analogue X-rays and digitization in DICOM compatible files.

A fourth PC is equipped with a DICOM viewer software and acts as a remote viewing station, in which students can examine useful DICOM file information such as header files and also perform a variety of image processing routines.

All PCs are Internet-enabled allowing students to gather relevant information from suggested Internet sites. At the same time the laboratory's network is equipped with remote viewing software that enables students to interact with other PCs and learn from their fellow students. The remote viewing software allows tutors to give a guiding tour to students on the basics of DICOM-PACS software. The software installed on the PCs may be either low-cost commercial software or software freely available on the Internet [5].

3. Educational Benefits

3.1 Training targets

The laboratory aims to provide in-depth training of undergraduate students on installing, setting up and utilizing DICOM–PACS software.

The training takes place in a virtual radiology department, where PCs act as medical equipment modalities and servers. The theoretical background on DICOM–PACS is provided by the relative theoretical course. The software used is fully functional and allows students to explore medical image transfer, processing and storage in a laboratory setting. The advantage of implementing a DICOM-PACS system in a laboratory over visiting medical sites is that students are trained on DICOM networks using a holistic experience, from installing to utilizing and troubleshooting DICOM-PACS networks, which would have never been possible in a continuously functioning radiology department. The medical ethical questions stated previously, arising from handling true medical records and medical software in operation are eliminated.

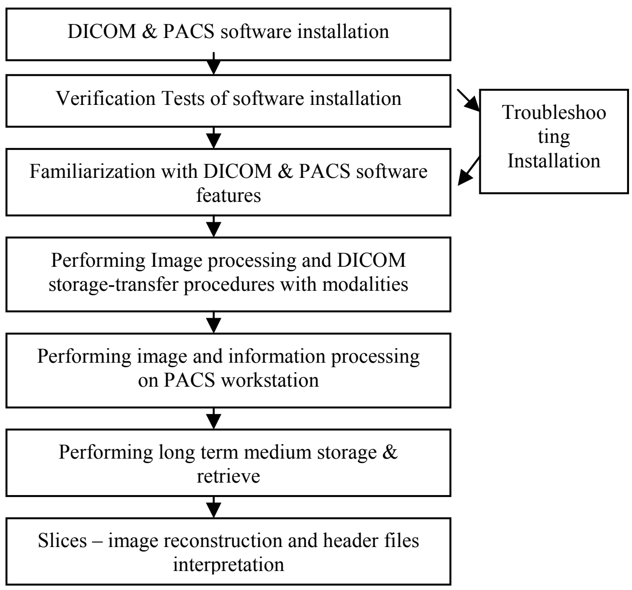

Fig. 2: Laboratory DICOM-PACS training steps

Students are guided through the installation procedures (figure 2), both for modalities and the PACS workstation, but the actual installation is performed by them. Once installation is done, several tests are performed to verify the installation process.

If tests fail students are given support to troubleshoot the installation procedure.

Once installation is verified the laboratory tutor gives an overview of the software characteristics and operation through network remote viewing software. Students are requested to perform DICOM gateway services, i.e. send DICOM files from modalities to the server, viewing and image processing operations, archiving and storing to long and short-term media, query and retrieve operations, digitization of film-printed radiographs and examination and interpretation of DICOM header files. Furthermore, during laboratory hours, students are encouraged to visit selected Internet resources as supplementary material to their laboratory notes.

3.2 Advantages gained through the student-centered approach

The traditional methodology of training visits to radiology departments in order to observe DICOM–PACS networks in use has several disadvantages as previously mentioned. Professional training, concerning non-university trainees usually takes place either at the site of installation or in special hands-on workshops offered by major vendors [6].

The philosophy of our Department's approach is more closely related to the workshops provided by vendors, but it is driven by the learner–centered approach [4, 7]. It encourages students to solve problems they will face in real life as Biomedical Engineers. The actual implementation of software installation, set-up and utilization aims to help students understand the necessity of having an appropriate theoretical background in the related topics of Computer Science, Network Engineering and Biomedical Engineering. Since collaboration and participation enhances the learning procedure, students are encouraged to do so, both with laboratory tutors and among them, using the remote viewing software installed on all PCs.

Recommendation of Internet resources and access to the selected sites during laboratory hours is enhancing students' participation in their learning process. Technology-enhanced, student-centered learning environments promote students' curiosity, by facilitating discovering and investigating, which is a very significant motivation to learn [7].

4 Conclusions

The simulated radiology DICOM-PACS network overcomes the disadvantages of teaching in real hospital installations. It also overcomes medical ethical dilemmas related to access and manipulation of medical data. The PCs network solution, equipped with appropriate software, is a low-cost alternative to buying DICOM-compatible medical devices.

The learning model used in the present application, which is also applied to the other laboratory courses involved in the framework of the project "Upgrading of Undergraduate Curricula of Technological Educational Institution of Athens" (APPS program - T.E.I. of Athens) [8], promotes the learning procedure by triggering students' self-activation, curiosity and participation. It is not supposed to fully overshadow existing traditional teaching methods, but is considered a necessary supplement of these methods.

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