WCL-Viewer: An integrated system for medical image administration and processing.

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Abstract: - The WCL-Viewer is an integrated medical information system with beneficial features regarding any prior implemented system up to present. It is a computer system infrastructure capable of storing, retrieving, transporting, displaying and printing medical images. It features admissions, discharge and transfer of data, hence the benefit for data validation and patient information update. It enables worklist management and prefetching of prior studies from long term archive to online storage and allows physicians to view and process or editing reports and images simultaneously. It was also designed and implemented as a strong educational tool, presenting features of retrieving prior reports and images, and even the opportunity for online education through a real time consultation of a study retrieved from a modality online. The WCL-Viewer was developed with close collaboration of doctors of medicine and engineers and is used as the basic operational tool in the Radiology Department of the University Hospital of Patras, Greece.

Keywords: - Picture archiving and communication systems, Hospital Information System, Diagnostic Viewing Station, Medical Image Processing, Telemedicine, Teleradiology, DICOM, HL7.

1 Introduction

Digital radiology in its most extreme form, the filmless Radiology Department / Hospital using a RIS/PACS-system for acquiring, reviewing, distributing and archiving image information, has until recently not really been established as a routine phenomenon. Today however, technology makes it possible to come true and also build networks of departments intercommunicating over large distances and at high speed. The filmless department is therefore a reality [1].

Medical images are at the heart of the healthcare diagnostic procedures. They have provided not only a noninvasive mean to view anatomical cross-sections of internal organs, tissues, bone and other features of patients but also a mean for physicians to evaluate the patient's diagnosis and monitor the effects of the treatment [2][3][4].

Wire Communications Laboratory - (WCL) Viewer, presented in this paper, consists of modules for image acquisition, archiving and retrieval, communication, image processing, distribution, and display of patient information [5][2]. The WCL-Viewer can also be used for education of medicine students and clinicians. The system offers an efficient means of viewing, analyzing, and documenting study results, and provides a method for effectively communicating study results to the referring physicians.

The WCL-Viewer was implemented to the University Hospital of Patras, Greece. It has been operational and under continues evaluation for a wide period of time now. This period of time has offered the opportunity to the users to conduct reports evaluating the system based on their personal experience.

2 The WCL-Viewer Architecture

The digital viewing application, shown in fig. 1, was developed for viewing and processing images of different modalities. As is customary, individual images or a series of images may be shown adjacent to one another at a workstation [6].

The images are organized in logical groups (maps). A map contains all images of a specific examination. Via a hierarchical examination of a patient map structure the images are managed in a local database with other examination data, such as demographic patient data, institute data and physician data. In addition to current examinations, archived images and reports can be displayed simultaneously. The archived images may be retrieved at any time from the archive.

The basic architecture of the WCL-Viewer is a 3-stage architecture:

- The first stage, which interacts with data stored in the database. It is able to provide automatic data management of archiving and retrieval (backup, restore etc) and immediate data access.

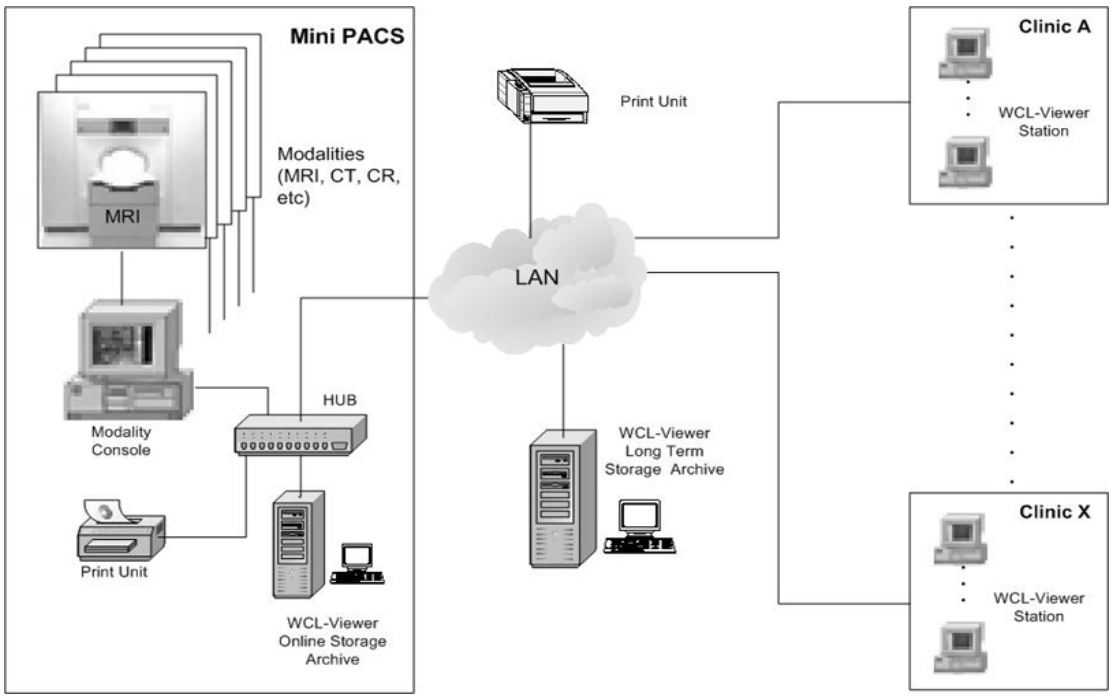

Fig. 1: WCL-Viewer Architecture

- The second stage, which includes rules and procedures on the data storage system to manipulate the database. It is able to manage the entire workflow process from data acquisition to data repository and to automate the loading, archiving, display and delivery of medical image data.
- The third stage, which includes the user access to the application. It presents patient data and images to the user and has an intelligent user-friendly interface [7] that allows users to easily capture, manage, index, interrelate and manipulate any medical image.

The WCL-Viewer was developed using Visual Basic for the interactive user interface and the Accusoft Medical SDK for the implementation of the image processing functions.

3 Protocols used

The application is based on DICOM 3.0 (Digital Image Communication in Medicine) standard [6] [8] for data communication, data storage and retrieval, and data processing purposes and HL7 (Health Level 7) [9] [10] for message exchange.

For the communication between different workstations and modalities a Fast ETHERNET is used and sessions using the ISDN network operating according to the H.320 standard [11].

The communication between the archive and the modalities, and between the archive and the PC viewing stations, uses the DICOM protocol and HL7. For better performance, the communication between the archive and the diagnostic workstations uses a proprietary protocol, allowing the workstations to have direct access to the archives database and to realize advanced functions such as the automatic update of worklists.

4 WCL-Viewer Facilities

The WCL-Viewer features an amount of facilities, which are described throughout the following paragraphs.

4.1 Data acquisition and storage facilities

An efficient archive of radiological images and medical information data must be able to safely store and retrieve large data sets in a very short time [12][9]. Table 1 presents typical memory requirements of different image techniques.

Table 1 – Typical size of medical images

Procedure	Typical picture size	Size of single image (Mbyte)	Typical number of images/ procedure	Total size (Mbyte)
Chest X-Ray	1760x2140	7.35	2	17.4
CT examination	512x512	0.52	40	21
MR examination	256x256	0.13	80	10.5

There is a main database where all the acquired DICOM files are stored. The image acquisition could take place either online or offline, through a LAN Network or even to a remote workstation, using TCP/IP. Storage is accommodated by short-term, local storage and long-term archive storage.

The stored data could also be past or current reports made for a certain patient (or generally collected, stored and processed non-image data associated with stored images) or even study files created by the referring physician after an examination.

A prototype feature of the database is that already examined stored studies can be used for educational purposes**.**

At the initiation of the storage process, the patient is registered (if not already) and all the data regarding the patient are sent to the WCL-Viewer storage archive. Procedure is performed and images are also sent to the archive. Then via a routing application all the data are stored to the archive, based on patient unique id number. At the end of the storage process all the data are available on demand [13].

4.2 Data viewing and processing facilities

The WCL-Viewer offers the ability to view and process image data acquired from various modalities, such as CT, MRI, CR, angio- (secondary capture and DICOM x-ray angiographic), ultrasound, nuclear-medicine, fluoroscopy and digitalized x-ray films.

It has most of the 2D image processing functions [14] (such as zoom in/out, magnifier, window level, smooth/sharp, annotations, pseudocolor, etc.), plus functions for multi processing and viewing of medical images, even up to 64 images at the same time (fig. 2), and display of multi-frame objects. MPR, MIP and surface shaded 3D-modelling are seen as an advantage.

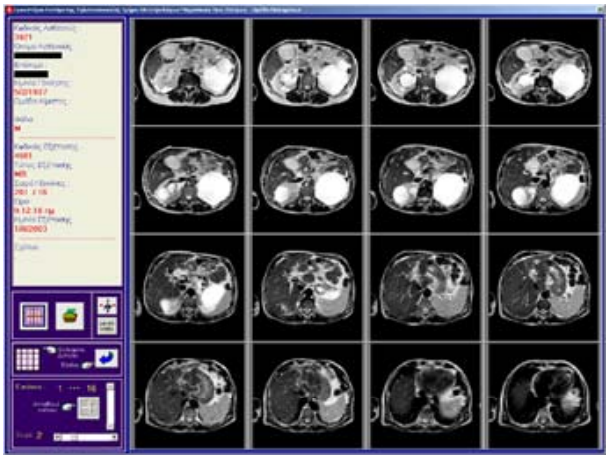

Fig. 2: Multi-process Screen

A function of the application was developed so the physician who studies an examination can extract or import the images with a finding, to a new file saved in the database (optional) and to form a report which will be printed along with the selected images. This function reduces the time required for post processing of the results of an examination and it will be rather easier for a review, if necessary (fig. 3).

Fig.3: Log Files Screen

The WCL-Viewer is compatible with the DICOM 3.0 standard. It uses the DICOM service classes DICOM storage SCU/SCP, DICOM query/retrieve SCU/SCP, DICOM Worklist support and DICOM print management SCU for the interaction with the medical modalities over the medical unit LAN implemented by the STORESCP functions.

4.3 Printing facilities

The application features DICOM Printing and Postscript printing, with custom size options. It is a single form used for print preview of a selected image (processed or not) of a medical study, providing options to the user for customization of layout, such as the size of the printed image, the process steps previously applied etc (fig. 4).

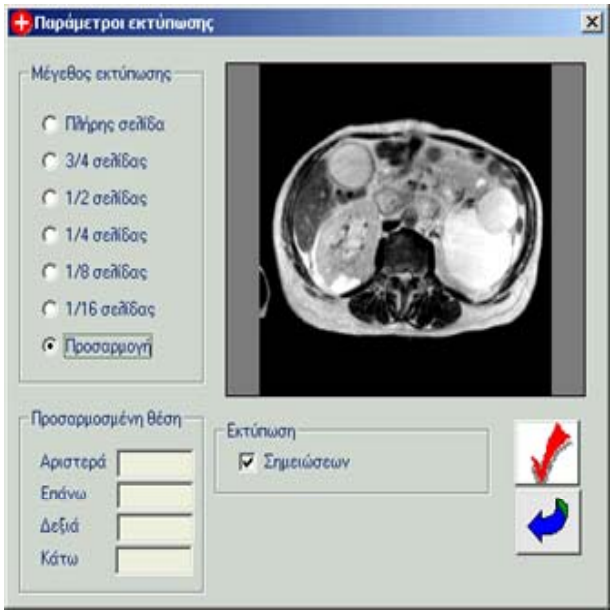

Fig. 4: Custom Print Management

4.4 Conducting a Report

WCL-Viewer, offers the opportunity of conducting a report after a study examination or review of previous

stored reports. This could result after collecting all the needed images from a medical examination, through the application and by writing a text report, which would be a diagnosis, a possible treatment, further reference or additional examinations etc. Upon the completion, a print option is available (fig. 5) and a save option, in order to store the report to the database.

Saved reports could either be available for educational purposes or be stored in the patient's log file.

Fig. 5: Completed Report

4.5 Teleconsultation facility

A special feature of the WCL-Viewer is the opportunity for teleconsultation between two remote users of the application. Even though it was primarily designed for communication between radiologists and modalities' operators, it was later expanded in order to include additional possibilities for consultation.

The real-time teleconsultation facility enables radiologists, modality operators, health care doctors and physicians to perform real time consultation between remote peers, based on medical images. The DICOM standard provides a way to communicate medical digital images between archives, so that a patient study can be sent in advance to the remote location, received by its DICOM archive (SCU), and viewed on both machines.

This could result to a dramatic time decrease of diagnosis through the real time communication primarily between the radiologist and the modality operator, as well as the hospital or medical institute (where the patient is) and the referring physician.

The supported features in the WCL-Viewer are:

- Still images exchange e.g. radiological examinations (X-ray, MR, etc.) and textual data.
- On-line marking and showing region of interest (annotations).
- Multi-image support.

4.6 Patient and Study Index Files

It supports index files for monitoring browsing patient records or images. There are two index files available, in the main screen. The first index file is a patient-based list, providing all the patients who have been under a medical examination, whereas the second index file is study-based list, providing all the available current and previous medical examinations stored in the database for a selected patient (fig. 6).

Fig. 6: Index Files Screen

4.7 Security

The system offers a user identification process, through a log in screen. At this point a user id (which is unique) and a user password (also unique) are required for the user to enter the application (fig. 7).

There is also a feature for encryption in remote working and in transferring data between different organizations or even among remote users. This security function is based on encryption according to ICD-10 standard [15] [16] and digital signature (regarding the diagnosis text). That provides a "fail-safe" storage, retrieval and delivery of the data, by ensuring that no changes have been made to the content, without authorization, whatsoever.

Fig. 7: Main Login Screen

4.8 Education

The WCL-Viewer implemented a prototype feature for educational purposes [17] by means of using several stored past reports created after medical examinations of a patient and retrieved through the application for viewing and training. This feature could also be used for consultation between the radiologist, the modality operator, and in addition, between the primary health care doctor and the physician. The main goal was to implement a function under which medicine students or staff of a health care institute could be easily trained and educated, avoiding the traditional way of film presentation and hard copy reports, through a friendly environment. So, under close collaboration with Medicine Professors and students, a feature of online, real time video-projecting in a classroom has been developed.

This could be made either on line, by a direct connection to a modality and therefore real time study of a medical examination or off line by retrieving a past made study from the database. That gives the opportunity of a "real" education or staff-training, under "actual" conditions.

5. Evaluation

Below, are reports made by several users after the extended use of WCL-Viewer in University Hospital of Patras. The outlines of those reports are:

- Offset expenses of film and related labor, and eliminate the problem of lost film that results in lost revenue and repeat exams.
- Save on square footage as existing file rooms decrease in size and new projects require smaller file management areas.
- Improve staff productivity through better accessibility to diagnostic results.
- Improve turnaround and quality of diagnosis through better access to comparative studies.
- Simplify operational workflow in diagnostic imaging services by automating the access to images and reports and making them simultaneously accessible to radiology and clinical staff. Improve the productivity of imaging devices through reduction in time spent filming and processing studies – time which is then available to do additional procedures.
- Physician will to reading cases directly from computer monitors (called "soft reads"). Implementation of WCL-Viewer with physician support has resulted in physicians being willing to convert to reading images from a monitor, stopping to continue "hard" reading from film.

All those stated above, even though noted by users, are features and advantages of a large number of PACS used and developed up to present. Yet in addition to all those benefits, WCL-Viewer provides even more, regarding any other PACS available today. Those are:

- It is completely user-oriented. It was designed under close collaboration with several doctors, clinicians and physicians. Their individual notes and guidelines, regarding the application's functionality and interface, was a catalytic factor to its final easy-to-use state of implementation.
- An extremely useful educational tool, easily comprehensive and accepted by the vast majority of either medicine students or hospital staff trained throughout the time space of implementation of the WCL-Viewer.
- WCL-Viewer managed a technological "completion" of many communication protocols, such as DICOM, H.320, TCP/IP, HL7 and ICD-10, so as all those to "cooperate" as a whole presenting no functionality problems, whatsoever.
- WCL-Viewer engulfs a part of messaging communication by using HL7 standard for this purpose. This feature provides an additional "safety", regarding safe data communication, process and delivery.
- WCL-Viewer adopts medical image data compression by using JPEG2000 compression techniques [18], which can compress the original data of the images up to 98.4% without any loss in their diagnostic information [19] [20].
- Finally, WCL-Viewer presents encryption and security. These feature added an obvious advantage, regarding the security of sensitive

medical data, such as diagnosis text and patients' personal medical data.

6. Conclusion

The strategic objective of the WCL-Viewer is to improve service to patients, radiologists and physicians. Improving operations within a department, although likely, should not be the top priority. WCL-Viewer is expected to speed decision-making and decrease the time to diagnosis and treatment compared to the existing systems (film-based or not) as physicians will have quicker, parallel and simultaneous access to their patients' imaging studies. It is also expected to implement a new era in education and training, replacing or "enhancing" the existing ways as the benefits are no less substantial.

The quality of work and education should also improve because of consistent image quality and faster, more complete interpretations made possible by the consistent availability of previous or complementary studies.

The consequent use of internationally recognized standards, especially the DICOM 3.0 standard for image communication, allowed the integration of systems from different vendors.

Additionally, its security features provide safe storage, retrieval and delivery of medical data, which makes WCL-Viewer a rather original and strong application for a range of implementation purposes, even as a commercial product.

References:

[1] Ratib OM, Valentino DJ, McCoy MJ, Balbona JA, Amato CL, Boots K, Computer-aided Design and Modeling of Workstations and Radiology Reading Rooms for the New Millennium, *Radiographics*, 20:1807, 2000.

[2] Michio Kimuraa et all, MERIT-9: a patient information exchange guideline using MML, HL7 and DICOM, International *Journal of Medical Informatics*, Vol.51, Issue 1, July 1998, pp. 59-68.

[3] Ean-Wen Huang, , a, Sheng-Hsiung Hsiaoa and Der-Ming Lioub, Design and implementation of a web-based HL7 message generation and validation system, *International Journal of Medical Informatics*, Vol. 70, Issue 1 , April 2003, pp. 49-58.

[4] Bernd Blobel and Martin Holena, CORBA security services for health information systems, International Journal of Medical Informatics, Vol. 52, Issues 1-3, October 1998, pp. 29-37.

[5] The International Society for Optical Engineering, PACS and Integrated Medical Information Systems: Design and Evaluation, *Proceedings of the SPIE*, Vol. 4323, 2001.

[6] National Electrical Manufacturers Association, Digital Imaging and Communications in Medicine (DICOM), PS 3.1-2000, 2000.

[7] Quiles J, Souto M, Tahocas P, Alergia A, Vidal J, User Interface design and evaluation of a DICOM based Digital Mammography Workstation, *12th Portuguese Conference on Pattern Recognition*, 2002, Aveiro.

[8] American College of Radiology, Diagnostic Imaging & Communications in Medicine (DICOM), 1997.

[9] George W. Beeler, HL7 Version 3—An object-oriented methodology for collaborative standards development, *International Journal of Medical Informatics*, Vol.48, Issues 1-3, 1998, pp.151-161.

[10] HL7 Standard "Clinical Document Architecture (CDA)" [http://www.hl7.org/].

[11] Narrow-band visual telephone systems and terminal equipment, *ITU-T Recommendation H.320*

[12] Ornes CJ, Valentino DJ, Yoon, HJ, Eisenman JI, Sklansky J, Search engine for remote database-aided interpretation of digitized mammograms, *Proc. SPIE Medical Imaging 2001: PACS and Integrated Medical Information Systems: Design and Evaluation*, Vol. 4323, 2001, p. 132-137.

[13] Campo C, Traina1 A, Retrieval of Medical Images by Content in a PACS, *XVI Brazilian Symposium on Computer Graphics and Image Processing*, 2003.

[14] Güld MO, Thies C, Fischer B, Keysers D, Wein BB, Lehmann TM, A platform for distributed image processing and image retrieval, *Proc SPIE 2003*, 5150:1109-1120.

[15] ICD-10 Procedure Coding System Draft Index and Tabular Volumes I and II and Training Manual, 3M Health Care, Wallingford, Connecticut, May 1997.

[16] The International Statistical Classification of Diseases and Related Health Problems, 10th revision, ICD-10, [www.who.int/whosis/icd10]

[17] Huang H, Liu B, Cao F, Zhou M, Zhang J, Mogel G, PACS simulator: a standalone educational tool, *PACS and Integrated Medical Information Systems: Design and Evaluation,* February 2002.

[18] JPEG and JPEG2000 compression standards, http://www.jpeg.org

[19] G. Anastassopoulos and A. Skodras, The effect of JPEG 2000 ROI coding in medical imagery applications", *Proc. 2nd IASTED International Conference in Visualization, Imaging and Image Processing*, ACTA Press, 2002, pp. 783-788.

[20] G. Anastassopoulos, A. Tsalkidis, I. Stephanakis, G. Mandellos and K. Simopoulos, Application of JPEG2000 compression in medical database image data, *Proc. Digital Signal Processing 2002*, Vol. II, 2002, pp. 539-542.