A DICOM GRAPHIC USER INTERFACE FOR PC'S: TOWARDS A HIERARCHICAL SYSTEM FOR DYNAMIC DIGITAL ANGIOGRAPHIC IMAGE STORAGE AND VISUALIZATION

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ABSTRACT-- The advent of DICOM (Digital Imaging Communications in Medicine) standard for medical images is producing an enormous demand on new algorithms and techniques for a true and integrated DICOM PACS (Picture Archiving and Communication System) system for hospitals and medical research institutes. This work describes one approach for such integration, it gives a new light over some methods of visualization, i.e., not only it has used Multimedia and Object Oriented language for the development of a still image viewer, but also this work describes a compression method and dynamic visualization for cine-angiographic studies achieving compression rates of up to 49:1, allowing any PC connected to the InCor's network in the near future to retrieve and display DICOM images. The viewer is part of a complete integrated project taking place at the Heart Institute - InCor, São Paulo, aiming the classification, transmission, visualization, processing and storage of medical images.

Key-words: DICOM, Medical Image Storage, Digital Cine-Angiography, Computer Image Viewers

INTRODUCTION

It is well known that huge amount of frames generated by the x-ray Cine-Angiography studies lead to a massive number of bytes to be stored in magnetic or magneto-optical media. Preliminary studies performed in x-ray rooms demonstrated that each exam generates ~1,000 frames per exam, or approximately 1 Gb of data per patient (1024x1024x8 each frame). Actually the transmission of 1 Gb takes ~20 minutes. At InCor the number of patients admitted per day for Angiography exams is about 45, then the total amount of bytes to be stored is ~45 Gb/day. These are astonishing figures even for the modern facilities available today. Compression techniques are used to reduce these figures to a more affordable level where it might be possible to store and retrieve exams on a near-on-line (within minutes) or off-line mode (within hours).

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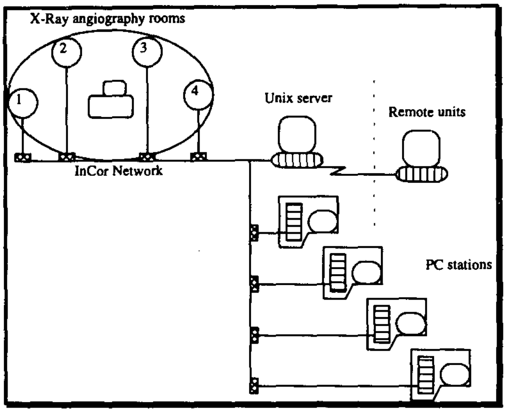

Figure 1- Diagram of the Angiography rooms connected to the InCor's network. the Philips Integris equipment transmits digital frames in ACR-NEMA format, not fully compliant with DICOM standard.

DICOM IN BRIEF

Digital Imaging Communications in Medicine, DICOM, is a framework for medical imaging communication. It is based upon the Open System Interconnect (OSI) reference model, which defines a 7-layer protocol model. DICOM was developed by the American College of Radiology (ACR) and the National Electrical Manufacturer's Association (NEMA), with input from various vendors, academia, etc. It is referred to as 'version 3.0' because it replaces versions 1.0 and 2.0 of the standard previously issued by ACR and NEMA, which was called the ACR-NEMA standard (ACR-NEMA, 1988). More recent the standard was recognized worldwide by most of the medical equipment manufacturers (RSNA, 1995) who are claiming compliance to the standard. DICOM provides: a)standardized formats for images; b) a common information model; c) application service definitions; d) protocols for communication.

INCOR'S ANGIOGRAPHY DEPARTMENT

Specifically, our x-ray Angiography department has acquired 3 complete Philips Integris 3000 systems, plus an upgrade for a forth x-ray room. All these systems are connected to our computer network as shown in Figure 1, being able to transmit a complete set of Philips proprietary ACR-NEMA frames (Philips Integris Manual, 1994) to a Unix server after each exam. The number of frames is variable from patient to patient, from 600 to 1,200 with resolution of 1024x960 and 8 bits depth. The ACR-NEMA format was not strictly followed by Philips therefore many data groups and elements were not included in the latest DICOM reference dictionary (DICOM, Part 6, 1995) leading to extra work for extracting standard information from the transmitted frames. Philips allocated 16 bits per pixel during acquisition, however used only 8 bits during transmission, zero-padding the other byte (Philips, 1994). Because of such allocation each frame transmitted from the

X-ray rooms through the network had 1,966,080 bytes times an average of 600 frames/exam lead to an estimated total of 1.15 Gb per exam, certainly an amount not easy to handle since the angiography department performs 45 exams per day or 10,000 exams per year.

REQUIREMENTS FOR THE PC'S VIEWER

To minimize the video memory problem (unfortunately the transmission protocol would remain the same according to Philips, until they become fully DICOM compliant) our viewer had to be planned to pack or re-size each incoming frame before executing any other task. These were the required features for the viewer:

- be able to receive and sort out a sequence of ACR-NEMA or DICOM images;
- be able to identify the format of the image, i.e., DICOM, ACR-NEMA.2* or ACR-NEMA.1* (DICOM, Part 10, 1995);
- be able to read each group and element of the header and compare it with a DICOM reference dictionary, displaying the relevant information into a scrollable list for easy reading of the detailed information as shown in figure 2;
- be able to identify the source of the image sequence: and if it comes from a Philips Integris then pack each other byte into one byte per pixel, eliminating the unwanted zero padded bytes as shown in Figure 3.

METHODS

Visualization and compression

To explain the visualization and compression model, a block diagram, as shown in figure 4, was built showing the major steps. Given that the Unix server (Sun Sparc station) would receive a sequence of raw data frames after each exam, the system should decide, (a) to store the sequence in a series of still frames or (b) and (c) to store the sequence in a moving picture archive. In any case, of course, the DICOM compliance might be kept allowing future data retrieval and exchange.

The following paragraphs describe the implemented decision model:

- To display-only the raw-data image sequence, the system should create a sequence of Device Independent Bitmaps (DIB), which can be interpreted by other platforms, i.e., Sun, HP, Alpha-Digital (Unix), PC (MS-Windows, 32 Mb.RAM/ 14" monitor/ resolution of 1024x768x256), Macintosh (System-7), etc.
- If the frame is Philips Integris then size it down to 512x480 due to the advantages in processing speed, storage space and image quality achieved with such image dimension for medical analysis (a point was made here by the physicians working with the system. It is very unlike up to now a physician can distinguish major problems with a full 1024x960 screen compared with a 512x480 frame. Further scientific studies are needed to balance the advantages and disadvantages

* ACR-NEMA.1 and ACR-NEMA.2 are version 1.0 and 2.0 of the standard, respectively

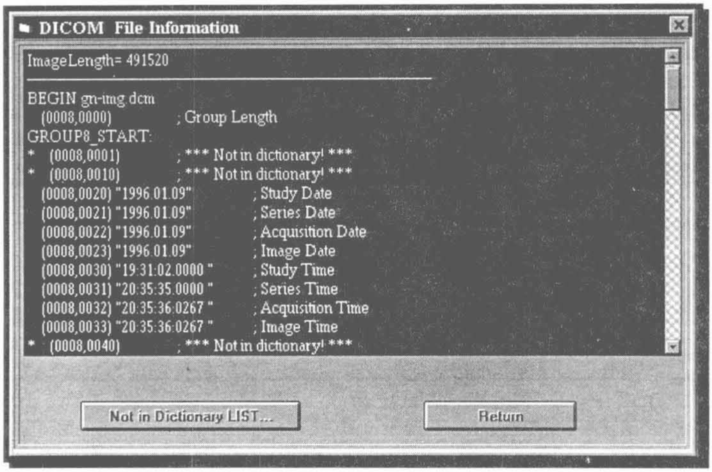

Figure 2- Window showing the image DICOM information using ASCII text in DICOMDIR format.

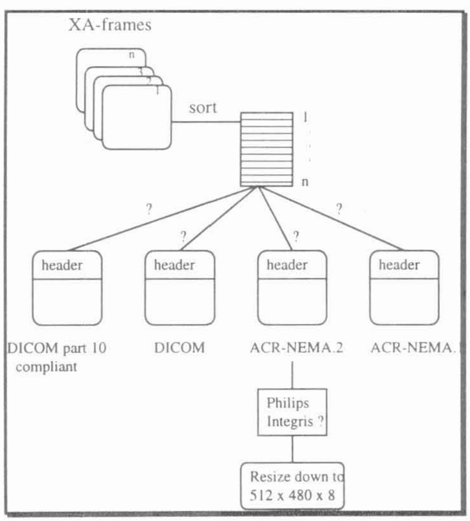

Figure 3- Diagram showing the sort and identification of each sequence in four categories: DICOM part 10, DICOM, ACR-NEMA.1 and ACR-NEMA.2. Case the image is from the Philips Integris sequence, then re-size each frame

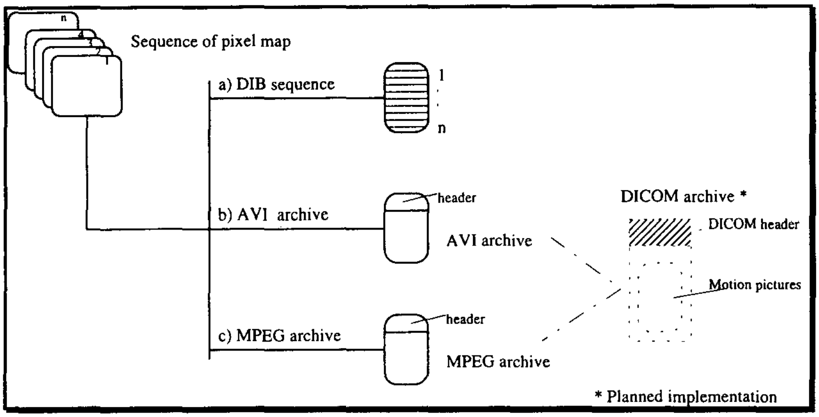

Figure 4 - Diagram showing the conversion of raw-data frames into three categories: DIB sequence, AVI archive and MPEG archive. A proposal to include Motion Pictures for XA (x-ray angiography) images is being submitted to the DICOM committee.

of this spatial resolution reduction on the diagnostic contents and clinical utility of angiographic images).

- To create a Microsoft Audio Video Interleaving (AVI) archive, for deeper compression rates, faster dynamic visualization, easy to develop interfaces, and to use the powerful Microsoft Multimedia Control Interface (MCI) routines, then create a DIB sequence in memory and afterwards apply the AVI functions to compact the DIB sequence into an AVI file.
- To create an MPEG (Motion Picture Expert Group) archive, for standardization, portability and best compression rates, then create a Portable Bitmap (PBM) sequence in memory and afterwards apply the MPEG algorithms for compression to compact the PBM sequence into an MPEG file. These steps are represented in Figure 4.

User Interface

A GUI (Graphic User Interface) has been developed using the most recent version of Visual Basic language, professional edition - VB 4.0 as shown in figure 5. Most of the libraries, called VBX's are 16 bits libraries, but they will be gradually upgraded to the new 32 bits OCX's libraries, using the new concept of OLE (Object Linked or Embedded), including migration to other systems such as Windows-NT and Open-VMS.

General routines for packing and converting images

The core of all functions for conversion and image packing has been developed using Borland C++ version 4.0 compiler. All functions and sub-routines are in ANSI C for portability to other platforms. The link between VB and Borland C is very appealing by the use of DLL, extracting the easy of prototyping from VB and the processing speed and code optimization from the Borland_C.

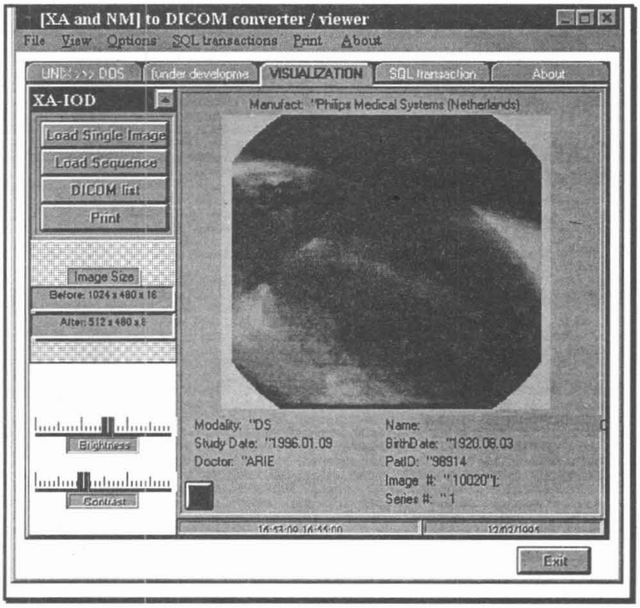

Figure 5 - DICOM XA (x-ray angiography) or NM (nuclear medicine) converter/viewer GUI, showing the main menu window, options and a typical digital angiography study

RESULTS

General looking of the interface

A compression ratio of 8:1 was observed immediately after re-sizing a frame (Philips Integris system only, because of the zero-padded byte), bringing each frame down from 2Mb to 240 Kb in size. All the information of the first frame header was saved in a scrollable list (figure 2) getting the image pixel information of the whole sequence thereafter. Figures (2 and 5 to 9) are 'cut-and-paste' pictures of the compiled PC-DICOM viewer system.

Compression ratios

With the use of a proper video codecs it was possible to reduce the XA- Philips Integris images with the following compression ratios:

- using DIB sequence: from 76.8 Mb raw-data to 9.6 Mb (8:1 compression ratio, 40 raw-data frames);
- using AVI compressor, 0.85 spatial quality factor, 0.75 temporal quality factor, 15 fps: from 9.6 Mb to 297 Kb (32.3 : 1 compression ratio, 40 frames of 512x480x8) as shown in figure 8;
- using MPEG compressor, NTSC mode, 352x240, 30 fps, integer DCT: from ~7 Mb to 142 Kb (49.3 : 1, compression ratio, 30 frames of 512x480x8) as shown in figure 9.

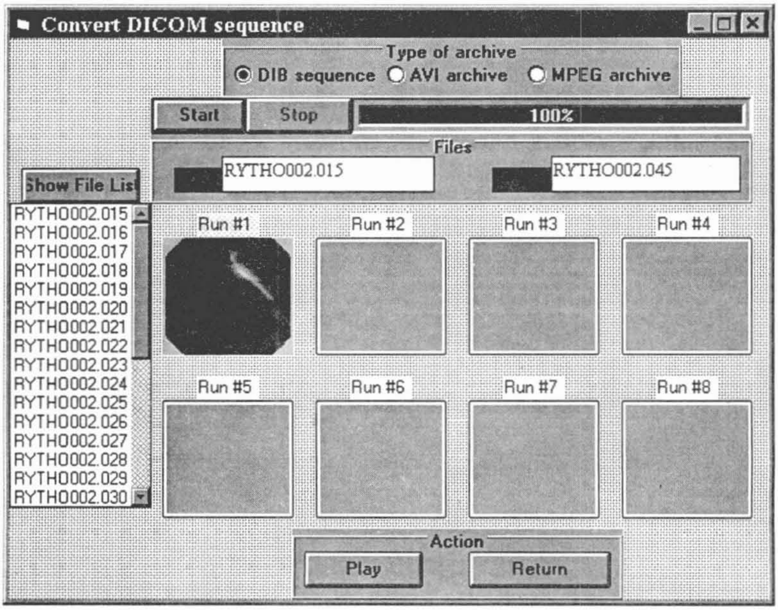

Figure 6- Window for conversion of image sequence from raw-data to DICOM standard. The user can select one or more image series from the same patient, and play the sequence.

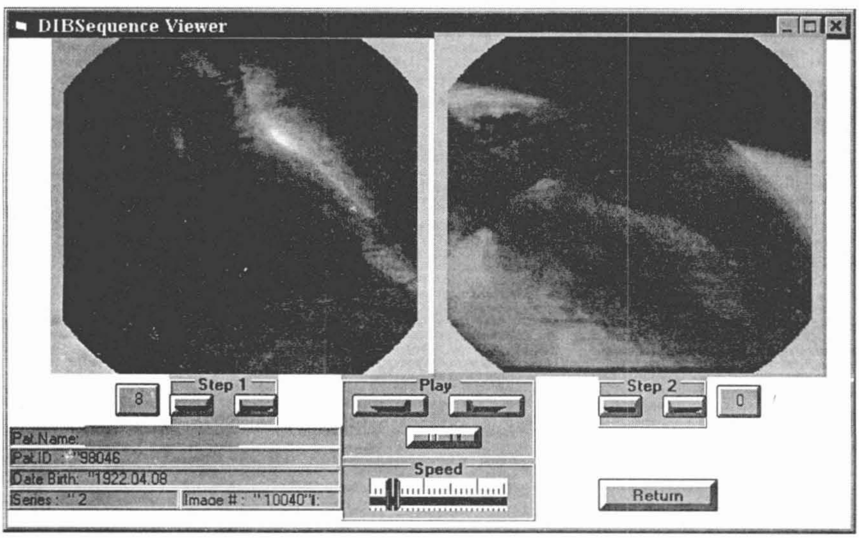

Figure 7- Window for DIB sequence visualization showing two images of different series. Also there is some patient information, read from the DICOM image header (leftside).

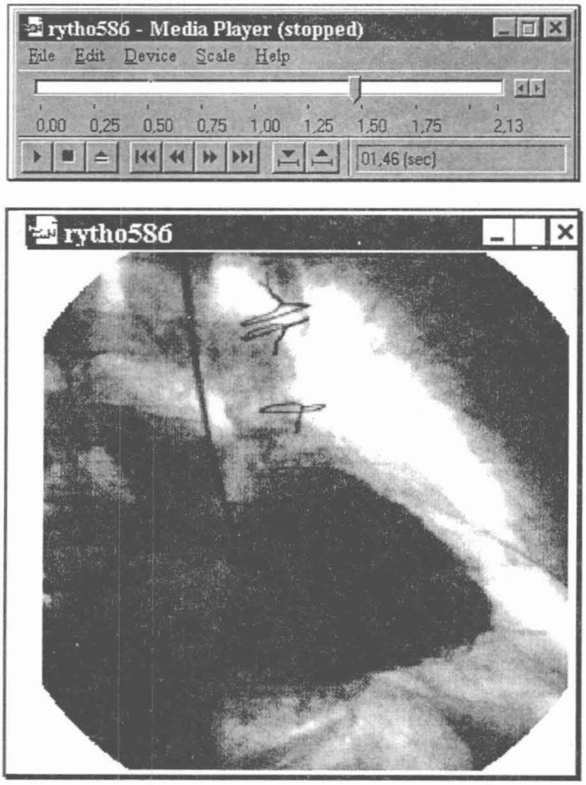

Figure 8- Window for AVI sequence visualization using resources from MS-Windows (Media Player) for playback. The image shows a heart and a contrast bolus being injected into the ventricles throughout a catheter. The player panel used for speed and step-by-step control is shown on top.

Data Interchange

A software interface for transferring a DICOM image or sequence of images to an Oracle Data Base, via WEB server transactions is under development. The interface is actually in C language, running in a Unix system, and is able to parse all the DICOM information down to the server, updating every related field in the DB. After transferring text and header information, the interface starts an image transfer, until end-of-image. Using specific information from the image header it is possible to create a Unique Identifier for each sequence to be stored, therefore this UID will be the key index for image sequence search within the Oracle environment. Also the GUI developed in the PC will have macros for SQL transactions, performing the same tasks as image transferring as the Unix interface does.

Figure 9- Window for MPEG archive playback with the same frame sequence from figure 8. Above, the MPEG-player panel used for dynamic visualization.

CONCLUSION

The system presented in this paper is suitable to be used in PC's under Windows 3.x or Windows'95 connected to a network. Many modifications are currently being done to improve the performance of the system. Because of its file name restriction, Windows 3.x doesn't accept Unix extended file names, but Windows'95 or NT does. Soon the DICOM viewer might migrate to one of these platforms. Also, according to the Part 10 of DICOM standard (DICOM, Part 10, 1995), all File Set stored in floppy disks must conform to the PC format for reading and writing. It means that each image name will have to be renamed using the 8:3 format (eight character plus three for extension), and moreover each File Set must comply to a directory structure called DICOMDIR (Elion, 1995), which is a hierarchical mode of information storage, starting by the Patient level and going down to the Study, Series and Image levels (Ratib, 1994). The implementation of DICOMDIR structure within the viewer is the next development step. Also for data management and data base queries a WWW interface is emerging as a mark for user inter-operability within the PACS system, thus probably most of the functional parts from the PC viewer will migrate to a universal WEB browser using HTML (Hyper Text Markup Language) or even the most recent JAVA script language which allows the user interface to be compiled in one platform but be executed in many, using WEB browsers such as Netscape which is able to read and interpret JAVA scripts. As more equipment get in conformity with DICOM, the tasks for reading and displaying DICOM images will be replaced by modeling, planning and analyzing of the image semantic, its meaning and fate. Browsers such as Netscape, HP, Mosaic, etc, are becoming more sophisticated and dynamic, allowing quick development of a total integrated system.

Data format

A new module of the XA-IOD is being suggested to the DICOM committee since the actual standard predicts only lossless JPEG compression on a frame-to-frame basis, including the header information in each frame (DICOM Part 4, 1995). This new module will bring more details about lossy compression using MPEG or AVI codecs, and it is an attempt to put the lossy compression for x-ray Angiographic images discussion forward.

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UMA INTERFACE GRÁFICA EM PADRÃO DICOM PARA PC: EM BUSCA DE UM SISTEMA HIERÁRQUICO PARA VISUALIZAÇÃO DINÂMICA E ARMAZENAMENTO DE IMAGENS DE ANGIOGRAFIA DIGITAL.

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RESUMO -- O advento do padrão DICOM (*Digital Imaging Communications in Medicine*) para imagens médicas vem produzindo uma demanda imensa de novos algoritmos e técnicas para o desenvolvimento de um sistema integrado de arquivamento e comunicação de imagens (PACS - *Picture Archive and Communication System*) para hospitais e institutos médicos. Este trabalho descreve uma abordagem de um visualizador de imagens DICOM para auxiliar nesta integração, esclarecendo alguns pontos nas técnicas de visualização não apenas utilizando de linguagem orientada a objeto e multi-mídia para o desevolvimento do visualizador, mas também usando de métodos de compressão e visualização dinâmica para os estudos de cine-angiografia, alcançando taxas de compressão de até 49:1, o que permitirá, num futuro breve, a qualquer PC conectado à rede de computadores do InCor buscar e visualizar imagens no padrão DICOM. O visualizador faz parte de um projeto integrado em andamento no Instituto do Coração, InCor, em São Paulo, visando a classificação, transmissão, visualização, processamento e armazenamento de imagens médicas.

Palavras-chave: DICOM, Cine-Angiografia Digital, Visualizador Computadorizado de Imagens, Armazenamento de Imagens Médicas

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