The global Image Management Strategy within the HUG

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Abstract

We present the overall strategy adopted by the University Hospitals of Geneva (HUG) for the medical image management. The core imaging facilities rely on a commercial PACS system deployed within the radiology department and on an hospital wide distribution through our home-made EMR application (Electronic Medical Record). Additional facilities include a teleradiology experience and image case collection. We describe technically and functionally those facilities and report the difficulties. The on-going challenges reside in the growing image production within radiology, the removal of the traditional film harcopies and the PACS extension to all hospital imaging sources.

Introduction

Our goal is to deliver a unified hospital-wide image management environment. The implementation strategy focus on the integration and workflow perspectives: IT integration via the use of medical standard such as DICOM (1) or HL7 (2), seamless integration between the different software environments and workflow integration consistent to the global patient care chain.

Our approach is a step-by-step one: we acknowledged the maturity of commercial PACS[1] solutions and therefore decided to rely on one. A multidisciplinary group representing radiology users and IT defined requirements and applied a call for tender. For deployment in radiology, we emphasized the process re-engineering, spped performance and IT integration. Once the user acceptance has been successfully reached in radiology, we moved to radiological image distribution to clinicians. We logically promote our home-made EMR[2] solution called DPI (*Dossier Patient Intégré*), as a federated access to medical information. The next step will be the PACS extension to all imaging sources within the hospital. We are pragmatic in the sense we acknowledge the existence of various mini-PACS needed to be progressively integrated within the institutional PACS infrastructure.

In parallel we are implementing added-value services that take advantage of the PACS infrastructure: image case collection is the best illustration. It is fully integrated to PACS and allows creation of teaching files that support the teaching activity. In the future, we intend to offer a wide variety of specific image processing tools.

Pacs within the radiology

Technical architecture. The PACS is a commercial system acquired via a call for tender launched in 1999. The system has been supplied by a consortium: it includes an image management server supplied by Image Devices GmbH (general contractor) (3), and reading stations delivered by CEDARA (4). Table 1 highlights the main facts.

- *Archive*. The archive management is a three-tier hierarchical storage: a 500 gigabyte magnetic disk (RAID[3]) as online, a 5-terabyte near-line archive (drive technology: 9.2 GB MOD[4]) and a 7 terabyte tape backup (drive technology: 100 gigabyte S-DLT[5]).
- *Imaging modalities.* The PACS is connected to 33 different imaging modalities using DICOM. Their standard compliancy profile includes DICOM *worklist* to retrieve the patient demographics, DICOM *store* to push images to PACS and DICOM *print* for hardcopy. The non-DICOM imaging devices such as our ultrasound units have been attached to a "DICOM box" (video-grabbing and conversion to DICOM).

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- *Reading station*: The reading stations have a dual monitor configuration. Initially, we selected high brightness 3 megapixel monitor but more and more we move to color flat screen which are widely accepted for CT and MRI reading. Two communication modes are handled between the reading stations and the PACS server: either image files are autorouted to station once acquired, either image files are retrieved via network once required and directly loaded. Performance standards are the following: 100 CT images loaded in 35 seconds when remotely accessed versus 15 sec when locally stored.
- The PACS is also integrated to our RIS (Radiology Information System) via a broker (supplier: MITRA) to transmit the patient demographics, study schedule information and signed reports.

Medical practice and user acceptance issues. The PACS is now widely used in a daily routine for more than three years and is fully accepted by radiologists. The major key success factor has been the intuitive and productive tools supplied by the softcopy software (automated viewing protocols, contextual menus). PACS introduction significantly changed the radiological workflow by a direct reading after acquisition. Five clinical rounds are daily performed in a computerized way (internal medicine, neurology, surgery) and CT, MRI are fully softcopy-based. However, some difficulties remain due to functional limitations:

- No possibility to build a dedicated worklist for clinical rounds and transfer it from a reading station to the other.
- Subsistence of hybrid workflow (coexistence of still paper based order with image softcopy) leading to serious organization problems. To address this issue, we started a RIS renovation project to unify all sources of information (order, preliminary and final reports) and worklists. It will be connected to our electronic order entry system (ORMED, home-made implementation).
- The nuclear medicine and radio-oncology sections can not yet fully rely on PACS due to DICOM integration problems and specific imaging visualization expectations. We consider to offer them alternative softcopy solutions specialized for these activities.
- Problems with the modality replacement. Regularly we are facing some DICOM integration problems impacting the daily routine. For instance some new modalities do not properly transfer information which are useful both for medical practice or automated viewing protocols. This situation remains even if we apply a selective strategy based on high-level DICOM conformance requirements.

Daily stored images	12000
Part of digital images on global image production	> 90%
Reading stations	25
Image production volume/year	2.5 Terabytes

Table 1: Facts

Hospital-wide distribution

Radiological images are distributed within the hospital through our EMR application called DPI (5). Image access is provided with other clinical information and lab results in an integrated way. The clinician logs on the EMR and loads the selected patient folder. The access rights policy is centrally controlled and any access is tracked within our audit trail system. Technically speaking, the image retrieval mechanism is performed in two steps:

- use of informational services to document the radiological record content. The supplied imaging list is displayed to user for study selection within the EMR;
- launching of a java applet viewer loading imaging studies or series from a central image repository acting as a web server.

The informational services are delivered through our middleware framework based on an HTTP-XML protocol (10) (queries structured in an XML dataset and transmitted through a http channel). These services provide the EMR with an exhaustive information set concerning the patient's radiological records (patient, study and series levels). Each series is documented by an icon path to offer a preview facility to doctor. Moreover, the XML service indicates the level of image availability within the PACS storage architecture (online, near line or backup level). By this way, he/she may anticipates the retrieval waiting time. Concerning the image display part, we offer an image viewer applet supplied by Image Devices GmbH. It is launched through the web (call of a servlet method via an url with the patient, studies and series identifications). This applet offers all basic display tools such as zoom, window/level adjustments, convenient browsing modes. We apply a selective viewer mode strategy to address the issue of limited resource availability on some low-end stations. Depending on the amount of free memory, one of the three viewer modes is used: simple HTML viewer based on JPEG images or either a 8-bit, either 16-bit image java viewer applet.

That image display capability has been introduced within our EMR application in early 2002 and is progressively expanded. Hundred image displays are daily requested to PACS.

Image case collection

PACS offers a patient-centered image storage and retrieval solution best suited for reading practice. However it lacks the ability to index studies using advanced criteria such as a medical context for instance. For that specific purpose we implemented Casim@ge (7) to create some teaching files for teaching and research purposes. This solution is implemented using the 4th Dimension DBMS software from ACI to allow rapid design. With this software, the three main functions are: a data import function fully integrated to PACS, data editing by means of simple and powerful client software and data sharing and distribution with the creation of stand-alone and multiplatform CD-ROMs and with a Web-server for online access.

In the medium term Casim@ge will include content-based image retrieval (CBIR) algorithms to retrieve similar cases for reading activity.

Teleradiology

- A specific experience is led with French neighbor hospitals in a neurosurgery application. The goal is to decide whether some trauma patients have to be transferred to Geneva for surgery. For that purpose, surgeons need to consult images acquired in those remote sites.
- We have implemented a web-based solution called TELIM. Communication is push-based on asynchronous and secured ways: images are initially sent from the imaging modalities to a local relay server where encryption is performed. As a second step, image files are transferred via HTTP to a HUG server installed on a semi-public domain network (behind our firewall). From this point, image files are automatically copied to an intranet server from which they become available to doctors.
- This preliminary experience will be extended to new sites in the future to scope other needs (second advice or patient transfer).
- As an alternative we have implemented a secure DICOM communication compliant to DICOM Supplement 15. Implementation (6) is based on OpenSSL library and ensures triple DES encryption and RSA based certificates for user authentication.

Challenges and future projects

The increasingly growth of image production within the radiology. The most challenging issue is the huge amount of images generated by the newest generations of functional MRI unit – up to 20'000 images per study - and multislice CT (MSCT), averaging 400

to 800 images per study with a 4-channel system. Our two 4-channel MSCT units will be soon upgraded to 16-channel MSCT channel. This heavy production load leads to severe performance problems on the reading stations. In order to accommodate our PACS with the increased image burden (yearly production growing from 2.5 to 3.8 Tera-bytes), we are currently moving to a selective archive strategy based on a thick-slice storage (3 to 5 mms). Raw data are only stored temporarily for image processing purposes or interpretation control if required. In a more general perspective, the interpretation of functional MRI or multi

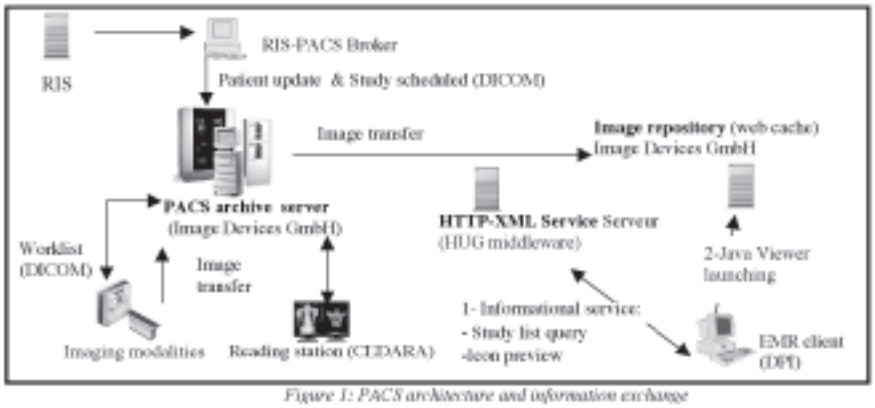

Figure 1: PACS architecture and information exchange

slice CT requires a new image navigation paradigm offering 3D navigation or hierarchical view on image (automated image fusion to have either thin or thick slice navigation). This paradigm requires a major PACS evolution.

Key image selection for clinicians. This method promotes the display to clinicians of significant images previously selected by radiologists. Nonetheless clinicians may access all images if wished at any time. This image selection facilitates the clinician consultation by highlighting the significant information. We failed to introduce this feature so far due to a delay in DICOM evolution and the non complete proprietary integration of the PACS suppliers. The new DICOM supplement (key image note) will definitely help us.

Hardcopy removal. Second challenge deals with the final removal of the film hardcopies. This removal will be introduced in two steps: removal in hospital once images are fully available within the EMR. For the outside distribution, we are currently investigating a distribution solution via CD-ROM given directly to patient when he/she leaves. This CD-ROM will store both image files embedded with a light DICOM viewer.

Seamless integration between RIS and PACS. Our current RIS is based on specialized software modules (scheduling, charge posting, dictation and finally report transcription). These modules share the same patient demographic information. However each module has its own user interface not seamlessly integrated with each other. Moreover they are based on different workflows. Therefore we are in the process of renovating our RIS:

- To offer a transparent access to all information and tools especially in the interpretation activity: transparent access to clinical indication, previous reports and images as well as access to dictation tool and report validation. This capability will rely on RIS / PACS / EMR client synchronizations.
- To have a central workflow enabling a unique view on any open jobs. We will rely on a generic workflow engine and on IHE[6] (11). IHE compliancy will ensure the best use of the DICOM and HL7 standards to integrate HIS, RIS, modalities and PACS.

PACS extension to all hospital imaging sources. We envision to open our PACS system to all medical images produced within the hospital. Indeed, specialties like cardiology, dermatology, ophthalmology, pathology or gastro-enterology heavily rely on image manipulation in their daily routine activity and wish to switch to a digital mode. In that respect, strategy is to provide a unified storage facility within the PACS and a unique distribution point via our EMR application.

To reach that goal, we need to take into account the heterogeneity of the installed systems. In that respect, two categories can be listed:

- Specialized image management systems, acting as mini-PACS. Examples are the pathology specialty having a network of microscopes connected to a system offering report tools and image display

and processing facilities (DIAMIC product supplied by INFOLOGIC) or the cardiology department equipped with a specific mini-PACS adapted to echo-cardiography needs (ENCONCERT solution supplied by PHILIPS). These solutions provide temporary storage. The need is therefore to automatically and regularly export images from these mini-PACS units for their long-term archiving within our institutional PACS.

- Digital devices (endoscopy units, microscopes, stroboscopes or small digital cameras). Such devices may be used to acquire color images –static or video - to be associated to any medical context (diagnosis, therapy preparation, follow-up). Clinicians or any other authorized operators expect to have a software utility to manually associate images to a specific patient and context or document.

Moreover we need to address the following issues related to DICOM standard and the large data volume:

- Unlike the radiology field, the majority of suppliers involved in other medical sectors do not support DICOM. This situation is mainly due to a low penetration of DICOM within those industry segments. But nevertheless DICOM effectively supports the corresponding images, especially through the visible light supplement (1). As an alternative, those suppliers opted for the different image formats used in the video industry. The most frequent formats are MPEG (8) or MJPEG[7] for motion image (11) or JPEG, TIFF for static image (9).
- DICOM lacks the ability to integrate some of these video formats with lossy compression (MPEG or MJPEG compression techniques for instance), even if there are some on-going discussions to support MJPEG codec in the DICOM Visible Light supplement.
- Most of imaging sources produce motion image (video) for which the volume can be important. It arises the storage strategy issue: do we need to archive all imaging loops or only selected ones relevant for the patient follow-up?

We are currently seeking the best solution to address these needs and issues. We are considering the following strategy based on image conversion services integrated to our middleware framework:

- Image files and their acquisition context are pushed via HTTP to a server where there are converted to DICOM and finally sent to PACS. The acquisition context is represented in a XML dataset built from a simplified DICOM information model: each XML tag matches a corresponding DICOM data element but we only transfer the most relevant information and all DICOM UIDs (Unique Identifiers) are generated afterwards. Rationale is that a DICOM-XML like format is more easily accepted by non-DICOM suppliers because it is more easier to implement.
- Static images are converted in a DICOM image format, the modality being either SC (Secondary Capture) or VL (DICOM Secondary Capture). The supported formats are JPEG and TIFF. If the source format is JPEG, we directly store the JPEG dataset within the DICOM image dataset without any decompression step.
- Video image case is a more complicated issue. Some major compression rates are applied at the acquisition level (roughly 20:1). Since these compression formats are not supported by DICOM we are facing a conversion problem. An uncompressed storage would seriously burden the PACS performance and capacity. In the same time, conversion from MPEG to a DICOM compression format, i.e. JPEG would introduce additional image quality degradation due to successive lossy compression oper-

ations. In that respect, we consider to keep the initial format and store it as a complementary file to DICOM studies. We would only extract a representative image from the loops and store it in DICOM in order to keep the DICOM arborescence structure (study and series). Videos would be displayed using freeware viewers.

Conclusion

Major achievements have been performed in term of infrastructure since the project launch in 1999: *(a)* a PACS deployed in radiology (1999-2000) and *(b)* an image distribution within the HUG-EMR since 2002. With the acquisition in 2003 of three new phosphor plate units, the radiology department will be fully digital (expect the mammography). We will therefore move forward to the complete filmless hospital: the last step being the extension to all imaging sources located outside the radiology. This new phase will start in 2003 and will address the issue of dynamic video and integration with heterogeneous specialized mini-PACS solutions. We will follow a customer focus approach by integrating the current working methods of each customer groups into the global patient care process. Our mission is to facilitate the workflow of clinicians using the best of new technology.

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Footnotes

[1] PACS: Picture Archiving and Communication System

[2] EMR: Electronic Medical Records

[3] RAID: Redundant Array of Inexpensive Disk

[4] MOD: Magneto-optical disk

[5] S-DLT: Super-Digital Linear Tape

[6] IHE: Integrating Healthcare Enterprise.

[7] MJPEG (Motion JPEG) video is essentially a sequence of JPEG stills playing. MJPEG is widely used for digitizing analog video.