PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (P.A.C.S.): Status, Problems, and Needs

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ANALYSIS OF THE EVOLUTION IN MEDICAL IMAGING

- Exploitation of an important number of physical phenomena
  (X rays, Gamma, NMR, thermographia, ultrasounds…)

- Evolution towards digital imaging:
  - Nuclear medicine (‘60)
  - CT scan (‘75)
  - Echography (‘80)
  - Digital angiography (‘82)
  - Magnetic resonance (‘82)

- Complementarity between different modalities
Introduction

Local Network

- Acquisition
- Archive
- Server
- Reprography
- Workstation
- Diagnostic
- ISDN Link
- 3D
Introduction

Why a PACS?

Statements in 1982:

a) Increase of digital modalities number

b) Loss of archives: 10-20%

c) Technological developments
Introduction
Why a PACS?

Advantages:

a) Decrease in losses of archives

b) + communication =>

+ productivity

- hospitalisation time

medical decision delay
Introduction

Why a PACS?

Advantages:

c) Cooperation

d) Decrease in direct and hidden costs

e) Data bases of images (reference)
Introduction

Why a PACS?

Drawbacks:

a) Cost of implementation

b) Flow rate

c) Standardization

d) Implication of medical staff
Technical specifications

Information flows identification

Qualitative aspects:
Type and origin of information, whether they are produced or used
- patient identification
- health care file
- exams demand and report
- exams data

Quantitative aspects:
Volume of produced information
Volume of used information (especially accesses to short term archive, medium term archive, and long term archive)
Access time, related to daily work load repartition.
Information flows identification
PACS DEVELOPMENT: GOLDEN RULES

MODULARITY

Definition:
- Independent modules carrying out the basic functions of the system
- Accurate specifications for INTERFACES between modules

Interest:
The system modularity is a necessary condition for further developments

Example:

<table>
<thead>
<tr>
<th>Server</th>
<th>Workstation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBMS</td>
<td>APP Comm</td>
</tr>
<tr>
<td></td>
<td>DB</td>
</tr>
</tbody>
</table>

Network

Interf H/M
GENERAL FUNCTIONALITIES OF A PACS

**INPUT:**
- sources of digital images, digitizers, reports
- other documents (signals, diagrams, …)

**OUTPUT:**
- visualization stations, reprographs (images and documents)

**MANAGEMENT of ARCHIVING:**
- images servers
- archiving strategy (short, medium, long term)

**COMMUNICATION:**
- between local systems
- through public networks (in and out)
Technical specifications

Networks

Three major topologies:

- STAR
- BUS
- RING
## Technical specifications

### Networks

<table>
<thead>
<tr>
<th>Physical Media</th>
<th>Flow (in Mbps)</th>
<th>Distance (in meters)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LAN</strong></td>
<td>Coaxial cable</td>
<td>10 hundreds</td>
<td>A building</td>
</tr>
<tr>
<td><strong>MAN</strong></td>
<td>FDDI</td>
<td>100 thousand</td>
<td>A campus</td>
</tr>
<tr>
<td><strong>WAN</strong></td>
<td>Misc.</td>
<td>0.92 to 2</td>
<td>National &amp; International long distances</td>
</tr>
</tbody>
</table>
The system has standard interfaces, allowing direct transfer of data.

Example: Ethernet interface and TCP/IP protocol, X25 interface, ACR-NEMA interface, or others (SCSI….)

In each case, those interfaces allow connections, but processing is needed:
- read data in the owners formats
- transform them into a standard format
- send them to an archiving system
Interconnexion of open systems: ISO model

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>règles liées au traitement de l'information (messagerie électronique, archivage électronique, etc...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESENTATION</td>
<td>règles de structuration des données (formats d'écrans, pages d'impression, ...)</td>
</tr>
<tr>
<td>SESSION</td>
<td>règles de synchronisation des partenaires de la communication, procédure régissant l'interruption et la reprise du dialogue</td>
</tr>
<tr>
<td>TRANSPORT</td>
<td>règles de contrôle du transfert de bout en bout du réseau (fiabilité du transport des données)</td>
</tr>
<tr>
<td>RESEAU</td>
<td>règles d'acheminement du message à travers le réseau (routage, contrôle du flux des informations, ...)</td>
</tr>
<tr>
<td>LIAISON</td>
<td>règles d'échanges d'un bloc d'information sur la ligne de transmission (détectio et correction des erreurs,..)</td>
</tr>
<tr>
<td>PHYSIQUE</td>
<td>caractéristiques physiques de connexion des équipements en termes électriques et mécaniques</td>
</tr>
</tbody>
</table>
ACR - NEMA: The DICOM Standard

Objectives:

Facilitate the communication of images from multivendors, by

1) defining an explicit model of real world with information objects (IOD) and service classes (DIMSE)

2) defining a file format and data encoding

3) defining a communication protocol
The DICOM Standard

Medical Imaging Application

DICOM Application Message Exchange

- DICOM
  - Session/Transport Network (STN)
  - Data Link
  - Physical (50-um)

DICOM Upper Layer protocol for TCP/IP

- OSI Association Control Service Element (ACSE)
- OSI Presentation Kernel
- OSI Session Kernel
- OSI Transport
- OSI Network
- LLC

Point-to-point environment

Standard network physical layers (Ethernet, FDDI, etc.)

Networked environment

Part 1: Overview

Part 2: Conformance

Part 4: Service Class Specifications

Part 3: Information Objects

Part 5: Data Structures and Semantics

Part 6: Data Dictionary

Part 7: Message Exchange (Network Operations)

Part 8: Network Support

TCP/IP & OSI

Part 9: Point to Point

Part 10: Media Storage & File Format

Part X

Part Y

Part Z

Specific Media Formats

& Physical Media

PARTS OF DICOM V3

Extensions to DICOM to support media storage
IMAGE COMPRESSION TECHNIQUES:

Definitions

Different approaches:
- Techniques with or without loss of energy
- Working domain used for compression
  - Real domain (spatial, time)
  - Transformed domain (Fourier, Hadamard, Cosine, Wavelets)
- Quantification method (scalar or vectorial)
- Coding method (RLE, Huffman, LZW,...)

Typical compression rates:
- without loss: 2 to 4
- lossy (DCT, JPEG): 10 to 16
- lossy advanced methods (factorial, wavelets, fractals): 40 to 100
Interest for a PACS:
- Very important reduction of data volume to be managed in the archiving system
- Reduction of flow rate necessary in communication systems

Problems raised by compression:
- The most interesting techniques induce an irreversible loss of information, that produces reserve from medical partners
- Hardware problems related to the introduction of compression circuits into the chain of production and use of images
- Organisational problems due to the windowing of images whose range needs more than 256 grey levels
**Interest: an example**

<table>
<thead>
<tr>
<th>Modalités</th>
<th>Volume pour une image</th>
<th>Volume/an (≥ 250 jours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>0,5 Mo</td>
<td>75 à 250 Go</td>
</tr>
<tr>
<td>IRM</td>
<td>0,5 Mo</td>
<td>70 à 300 Go</td>
</tr>
<tr>
<td>US</td>
<td>0,35 Mo</td>
<td>1 à 12 Go</td>
</tr>
<tr>
<td>Angio</td>
<td>1 Mo</td>
<td>17 à 4000 Go</td>
</tr>
<tr>
<td>Rx</td>
<td>20 Mo</td>
<td>500 à 800 Go</td>
</tr>
</tbody>
</table>

Total = 0,5 à 5 To / an

Exemple: Etude RMN
256 x 256 x 100 coupes
occupe environ 50 Mo

Image compressée occupe entre 1 et 2% de cette taille
INTEGRATED MANAGEMENT OF MEDICAL INFORMATION

What kind of data?

Administrative Data:
- Patient identification
- Consultation planning
- Billing elements

Medical Data:
- Clinical data (medical file of the patient in the care unit)
- Lab exams
- Imaging exams
- Medical archives
PACS needs: 6 user classes:

- **STATISTICAL QUERIES**
  - "How many MRI images were acquired in January 1997?"

- **RESEARCH QUERIES**
  - "Find all images acquired within the past two years diagnosed with right pleural effusions."

- **ACQUISITION TASK**
  - "Here is a new image. Make it available to your PACS users."

- **WORKSTATION USER**
  - "Display all available images for patient Smith, John, and all related text information."

- **RESOURCE MANAGEMENT**
  - "List the patients and images most active during the past week."

- **PACS (RIS) TECHNOLOGIST**
  - "Find the storage location of all images for patient 123-45-67. Give me this subset of images."

*(d’après Comp.Med.Imaging.Graph.)*
CHOICE OF AN ARCHIVING SYSTEM

Centralized system
Advantages: simplicity
Drawbacks: high sensitivity to failures

Distributed systems
Advantages: modularity, flexibility, increased security
Drawbacks: complexity, access protocols
STORING AND ARCHIVING STRATEGY

![Diagram showing storing and archiving strategy with timeline and storage options like RAM, dynamic, magnetic disk, jukebox, and offline storage options.]

off line
Evaluation

Since 1992: a maturity of the concept

1) Large scale advanced projects
   (Rennes, Lux, Genève, UCLA, EURIPACS, MIMOSA, ...)

2) Emergence of a stable standard: DICOM (Digital Imaging and Communication systems)

3) Emergence of ATM protocol, allowing high speed communications (up to 2Gb/s)
Evaluation

Remarks:

1) The cost of PACS is a true question: need of a diminution

   Expected out of the radiology department

2) Softwares are strongly machine-dependent

3) Local PACS or regional extension?

4) PACS and Teleradiology: which link?
FUTURE TRENDS ABOUT P.A.C.S.

**Multimodality images acquisition**: normalisation Dicom-style

**Communications**: FDDI, ISDN, ATM, INTRANET/INTERNET

**Compression**: lossless, lossy, quality factors

**Archiving**: adapted capacities, access time (prefetch), medium

**Modelisation tools**: pre-simulation

**Workstations**: Man/machine Interfaces,
Software based on HTTP, JAVA and Web technology
Simulation tools
Simulation tools
SOME P.A.C.S. EXAMPLES
Le réseau d’imagerie du CHU d’Angers
MIRIAM
Management Informatisé de la Radiologie et de l'Imagerie Médicale

( Source: Assistance Publique des Hopitaux de Paris )

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Réseau d’imagerie du C.H.U de Nantes

BM06- Chapitre 10: PACS
Lerallut, Medina, Azpiroz
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Topologie du P.A.C.S. du CHL de Luxembourg
Fig. 1b. UCLA PACS network: Medical Plaza ambulatory care center.
Fig. 2. University of Florida: Clinical and research network configuration.
Figure 1: The SMZO PACS Concept in the Radiology dept., as described in the text