Case Study: Medical Imaging; From Toolbox to Product to Platform

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Abstract

Medical Imaging was an early large scale Object Oriented product. Originally intended to become a re-useable set of toolboxes, it evolved in a family of medical workstations and servers.
This article describes the evolution from different viewpoints, to serve as background material for a number of case studies of the Gaudí project.

Distribution

This article or presentation is written as part of the Gaudi project. The Gaudi project philosophy is to improve by obtaining frequent feedback. Frequent feedback is pursued by an open creation process. This document is published as intermediate or nearly mature version to get feedback. Further distribution is allowed as long as the document remains complete and unchanged.

September 9, 2018
status:    preliminary
draft
version: 0.4
Philips Medical Systems, schematic organization

Philips Medical Systems

US

Non X-ray modalities

MR

CT

Medical Imaging

Conventional X-ray

Cardio Vascular

URF

Surgery

Common X-ray Components
Generic drivers of Radiology Departments

- Diagnosis
  - Image quality
  - Relaxed patient
    - ease of use
    - patient handling
    - universality
  - integrated information flow
  - minimal film cost
  - up time

- Department Efficiency
  - automation
  - patient accessibility
  - patient entry, exit

- Safety
  - Compliant with Standards and Regulations
  - minimal evasive
  - dose reduction
Phases of Medical Imaging

- 1991-1992 Development of 1\textsuperscript{st} product: Medical Imaging R/F
- 1992-1994 Parallel Development of 2\textsuperscript{nd} product: Medical Imaging CT/MR
- 1994-1997 Family Development
- 1997-2000 Transformation in re-useable components
Technology innovations by Common Viewing

- Standard UNIX based workstation
- Full SW implementation, more flexible
- Object Oriented design and implementation (Objective-C)
- Graphical User Interface, with windows, mouse et cetera
- Call back scheduling, fine-grained notification
- Data base engine, fast, reliable and robust
- Extensive set of toolboxes
- Property based configuration
- Multiple coordinate spaces
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X-ray rooms from examination to reading around 1990

Examination Room | Control Room
---|---

Corridor or closet

Examination Room | Control Room
---|---

Reading Room
X-ray rooms with Medical Imaging applied as printserver

Examination Room
- X-ray source
- Detector

Control Room
- Console

Corridor or closet
- Printer

Reading Room
- Light box
Comparison *screen copy vs optimized film*

old: screen copy

new: SW formatting

20 to 50% less film needed
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#### Medical Imaging R/F

<table>
<thead>
<tr>
<th>Print</th>
<th>Store</th>
<th>View</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spool</td>
<td>HCU</td>
<td>Store</td>
<td>Image</td>
</tr>
<tr>
<td>RC driver</td>
<td>HC driver</td>
<td>DOR driver</td>
<td>Gfx</td>
</tr>
<tr>
<td>RC interf</td>
<td>HC interf</td>
<td>DOR</td>
<td>UI</td>
</tr>
<tr>
<td>Standard IPX workstation</td>
<td></td>
<td></td>
<td>DB</td>
</tr>
<tr>
<td>Desk, cabinets, cables, etc.</td>
<td></td>
<td></td>
<td>PMS-net in</td>
</tr>
<tr>
<td>DSI</td>
<td></td>
<td></td>
<td>PMS-net out</td>
</tr>
</tbody>
</table>

#### SunOS

- NIX

#### Start up

1. Install
2. Config
3. SW keys
4. service
5. dev. tools

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September 9, 2018
MiLayers1992
Example Multi Planar Reconstruction

- Curved slice
- Oblique slices
- Curved slice
### Medical Imaging CT/MR
- Specialized applications (Dental, etcetera)
- MR
- CT
- RF
- Vascular
- Cardio
- PCR

### Specialized applications
- Compose
- Print
- Store
- MPR
- View
- Export
- Cluster

### CDSpack
- Spool
- HCU
- Store
- Image
- Gfx
- UI
- DB
- PMS-net in
- PMS-net out

### Solaris
- NIX

### Standard IPX or Sparcstation 5 workstation
- DOR
- Driver

### Desk, cabinets, cables, etc.
- RC dials
- HC dials
- DOR

### Remote access
- Install
- Config
- SW keys

### Customization
- Start up
- SW keys

### Development tools
- Service
- Customization
- Remote access

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**MLayers1994**
Example CT/MR department

MR Examination
room

Control
room

"MPR"
room

CT Examination
room

Control
room

Reading
Room
Differences between modality images

<table>
<thead>
<tr>
<th></th>
<th>X-ray</th>
<th>CT</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>image</td>
<td>projection</td>
<td>slice</td>
<td>slice</td>
</tr>
<tr>
<td>structure</td>
<td>single image</td>
<td>stack</td>
<td>stack</td>
</tr>
<tr>
<td></td>
<td>or time series</td>
<td>or volume</td>
<td>or more complex</td>
</tr>
<tr>
<td>greylevel mapping</td>
<td>contrast</td>
<td>window width</td>
<td>window width</td>
</tr>
<tr>
<td></td>
<td>brightness</td>
<td>window level</td>
<td>window level</td>
</tr>
<tr>
<td>resolution</td>
<td>$1024^2$</td>
<td>$512^2$</td>
<td>$256^2$</td>
</tr>
<tr>
<td>contrast noise ratio</td>
<td>10 bit</td>
<td>12 bit</td>
<td>8 bit</td>
</tr>
<tr>
<td>value</td>
<td>absolute</td>
<td>acquisition dependent</td>
<td>acquisition dependent</td>
</tr>
</tbody>
</table>
Specification Differences

- viewing and print preparation
  - navigation support
- multi-image view
- greylevel control
- specialized clinical functions
  - vascular and cardio analysis (X-ray)
  - dental (CT)
- print protocols
- information model
Medical Imaging Competitive Positioning

PACS products
Medical Imaging Review
GE Siemens workstations
Medical Imaging R/F and CT/MR

Clinical or modality value
Radiology Department

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Vision: Medical Imaging in Healthcare

Radiology department

- Radiologist at home
- Radiologist somewhere in the hospital
- Radiologist at other hospital
- Referring Physician
- Referring Physician
- Conference room

IT infrastructure in basement

Operating theatre

trauma room

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Idealized layers 1996

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Mlayers1996
System Level Documents: Root

- List of system level document lists
- System level requirements, specification and design documents
- System aspect documents
- Feasibility reports
• Cluster, interoperability documents
• Functional Specifications X-ray
• Functional Specifications CT/MR
• Application SW design
• System Software design
• Hardware documents
Documents

- Product Structure
- System Engineering requirements
- Design overview
- Hazard analysis
- Verification specification X-ray
- Verification specification CT/MR
Aspect Documents

- Cluster design
- HW Configuration
- CPU resource usage
- Disk resource usage
- Memory resource usage
- Requirements system monitor
- Safety
- Security
- SW process structure
- Testability and Service tools
- Installation, Configuration and Start-up design
- CT/MR image quality
- R/F image quality
- CT/MR typical load
- R/F typical load
Example Memory Budget

<table>
<thead>
<tr>
<th>budget in MBytes</th>
<th>X-ray</th>
<th>CT/MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>code</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>non bulk data</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>bulk data</td>
<td>36</td>
<td>88</td>
</tr>
<tr>
<td>Unix</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>total used</td>
<td>77</td>
<td>133</td>
</tr>
<tr>
<td>physical memory</td>
<td>64</td>
<td>128</td>
</tr>
</tbody>
</table>