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

by Gerrit Muller University of South-Eastern Norway-NISE

e-mail: gaudisite@gmail.com
www.gaudisite.nl

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.
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
  - Compliant with Standards and Regulations
    - minimal evasive

- Safety
  - automation
  - patient accessibility
  - patient entry, exit
  - dose reduction

Case Study: Medical Imaging; From Toolbox to Product to Platform
3
Gerrit Muller
Phases of Medical Imaging

• 1987-1991 Advanced Development ("Common Viewing"), result: Basic Application plus toolboxes
• 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
Idealized layers september 1991

SunOS, SunView

Basic Application

Image  Gfx  UI  DB

Standard Sun workstation

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

Control Room

Corridor or closet

X-ray source

detector

printer

Reading Room

light box
Comparison *screen copy vs optimized film*

old: screen copy

new: SW formatting

20 to 50% less film needed
# Case Study: Medical Imaging; From Toolbox to Product to Platform

**version:** 0.4  
**September 6, 2020**

## Idealized layers september 1992

<table>
<thead>
<tr>
<th>Start up</th>
<th>Install</th>
<th>Config</th>
<th>SW keys</th>
<th>service</th>
<th>dev. tools</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Spool</th>
<th>HCU</th>
<th>Store</th>
<th>Image</th>
<th>Gfx</th>
<th>UI</th>
<th>DB</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC driver</td>
<td>HC driver</td>
<td>DOR driver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PMS-net in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RC interf</th>
<th>HC interf</th>
<th>DOR</th>
<th>Standard IPX workstation</th>
<th>Desk, cabinets, cables, etc.</th>
</tr>
</thead>
</table>

| DSI | 3M | RC |

**Medical Imaging R/F**

- **Print**
- **Store**
- **View**
- **Cluster**

**NIX**

SunOS

**Spool**

**HCU**

**Store**

**Image**

**Gfx**

**UI**

**DB**

**PMS-net in**

**PMS-net out**

**Spool**

**HCU**

**Store**

**Image**

**Gfx**

**UI**

**DB**

**PMS-net in**

**PMS-net out**

**RC driver**

**HC driver**

**DOR driver**

**RC interf**

**HC interf**

**DOR**

**Standard IPX workstation**

**Desk, cabinets, cables, etc.**

**DSI**

**3M**

**RC**
Example Multi Planar Reconstruction

oblique slices

curved slice
Example CT/MR department
## 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

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

- Clinical or modality value
Radiology Department
<table>
<thead>
<tr>
<th>Back-ends</th>
<th>Image Guided Surgery</th>
<th>Review</th>
<th>Rad</th>
<th>CT/MR</th>
<th>XRay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialized applications (Dental, bolus chase, cardio analysis, etcetera)</td>
<td>Interfacing RIS, etcetera</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MR</td>
<td>CT</td>
<td>RF</td>
<td>Vascular</td>
<td>Cardio</td>
<td>PCR</td>
</tr>
<tr>
<td>Compose</td>
<td>Print</td>
<td>Store</td>
<td>MPR</td>
<td>View</td>
<td>Export</td>
</tr>
<tr>
<td>Spool</td>
<td>HCU</td>
<td>Store</td>
<td>Image</td>
<td>Gfx</td>
<td>UI</td>
</tr>
<tr>
<td>RC driver</td>
<td>HC driver</td>
<td>DOR driver</td>
<td>NIX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solaris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Sparcstation 5 workstation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC dials interf</td>
<td>HC interf</td>
<td>DOR</td>
<td>Desk, cabinets, cables, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC dials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>new HCU</td>
<td>MR</td>
<td>CT</td>
<td>DSI</td>
<td>DCAS</td>
<td>PCR</td>
</tr>
</tbody>
</table>
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>