Threads of reasoning illustrated by medical imaging case

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Abstract
The medical imaging workstation case is introduced. An architecting method based on the CAFCR viewpoints is explained, consisting of 4 elements:

• the CAFCR viewpoints
• qualities as integrating needles
• story telling
• threads of reasoning

A thread of reasoning is build up in steps, based on this case. The underlying reasoning is explained.
Easyvision serving three URF examination rooms

URF-systems

EasyVision: Medical Imaging Workstation

typical clinical image (intestines)
X-ray rooms from examination to reading around 1990

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XRaysRoomsOld

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X-ray rooms with Easyvision applied as printserver

Examination Room

Control Room

Corridor or closet

Detection

Console

Printer

Reading Room

Light box
Comparison screen copy versus optimized film

old: screen copy

new: SW formatting

20 to 50% less film needed
Challenges for product creation

ca 1 film / minute
film = 4k*5k pixels

subsecond retrieve
screen = 1k*1k

print
throughput

view
response time

image quality
image processing

tension

product policy:
standard HW
SW "only"

40 MHz CPU
64 MByte memory
10 MBit/s ethernet
1 GByte disk

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IMIchallenge
Top level decomposition

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CAFCR viewpoints

What does Customer need in Product and Why?

Customer
What

Customer
How

Product
What

Product
How

C Customer objectives

A Application

F Functional

C Conceptual

R Realization

drives, justifies, needs

enables, supports
Quality needles as generic integrating concepts

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QNneedles
From story to design

What does Customer need in Product and Why?

Customer
What
Customer
How
Product
What
Product
How

What does Customer need in Product and Why?

Customer objectives
Application
Functional
Conceptual
Realization

market vision
a priori solution knowledge

story
analyze design

analyze design
case
design

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SHTfromStoryToDesign
Chronology of Easyvision RF R1 development

1991
- basic application
- toolboxes
- 100 kloc
- interactive viewing

1992
- performance problems
- IQ problems
- Easyvision RF
- integrated product
- 360 kloc
- print server +
- communication +
- interactive viewing

marketing opinion:
"All the functionality is available, we only have to provide a clinical UI"
Thread of reasoning based on efficiency-quality tension

Customer objectives
- time efficient
- diagnostic quality
- safety (liability)

Specification issues
- system response
- system throughput

Concepts
- resource management
  - processor, memory
- internal logistics
  - concurrency, processes

Customer objectives

Application

Functional

Conceptual

Realization

Concurrent, processes

Image processing

Algorithms
Technology innovations

performance
cost

standard UNIX based workstation
full SW implementation, more flexible
object oriented design and implementation (Objective-C)
graphical User Interface, with windows, mouse etcetera
call back scheduling, fine-grained notification
data base engine, fast, reliable and robust
extensive set of toolboxes
property based configuration
multiple coordinate spaces
Thread of reasoning; introvert phase

Introvert view: cost and impact of new technologies
Memory usage half way R1

![Diagram showing memory usage](image)

- **Total measured memory usage**
  - **OS**
  - Code
  - Data
  - Bulk Data
  - Fragmentation

- **Performance**
  - 0 MB
  - 64 MB
  - Memory usage

- **Physical memory**
  - Paging to disk

- **Memory usage**
  - 64 MB
  - 200 MB

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MSmemoryZeroMeasurement
Solution of memory performance problem

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MSmemoryUsageReduction
Visualization memory use per process

- shared libraries
- UI
- communication
- server
- storage server
- print server
- other

MByte

- data
- code

measured (left column)
budget per process (right column)

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MSmemoryBudget
Typical case URF examination

3 examination rooms connected to 1 medical imaging workstation + printer

examination room: average 4 interleaved examinations / hour

image production: 20 1024 2 8 bit images per examination

film production: 3 films of 4k*5k pixels each

high quality output (bi-cubic interpolation)
How to measure memory, how much is needed? from introvert to extrovert
Radiologist workspots and activities

Examination Room

light-box

auto-loader

dictation room

supervision of the examination

view and diagnose, dictate report

verify and authorise report

activities of the radiologist
Diagnosis in tens of seconds

Films loaded by clinical personnel during the day

Light-box

Auto-loader

Looks at images

Moves head forward / backward

Moves head or eyes left/right/up/down

Zoom in

Overview

Image selection, panning

Mumbles a few Latin words or clinical codes in recorder

Presses next button

New films

Old films

Report

Tens of seconds
Rendered images at different destinations

**Screen:**
- low resolution
- fast response

**Film:**
- high resolution
- high throughput

**Network:**
- medium resolution
- high throughput
SW Process structure 1991

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MITORsoftwareProcess1991

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SW layers 1991

Medical Imaging R/F

Print  Store  View  Cluster

Spool  HCU  Store

RC  driver  HC  driver  DOR  driver

RC  interf  HC  interf  DOR

Image  Gfx  UI  DB

PMS-net in  PMS-net out

SunOS, SunView

Standard Sun workstation

Desk, cabinets, cables, etc.

Legend

User interface

Application functions

Toolbox

Operating system

Hardware

Sw infrastructure

Connected system

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MITORswLayers1991
Print server is based on banding
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Radiologists diagnose from film, throughput is important. Extrovert view shows conceptual and realization gaps!
Image quality and safety problem

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Presentation pipeline for X-ray images

- Image from database
- Spatial enhancement
- Interpolate (bi-linear, bi-cubic)
- Look up table (invert, contrast/brightness)
- Graphics merge
- Colour LUT
- Monitor

Legend:
- SW
- HW
Image Quality expectation WYSIWYG

X-ray system

- image generation
- presentation

Easyvision

- application processing
- presentation

3rd party workstation

- monitor
- film
- network, storage

monitor

film

network, storage

what you see at one work-spot is what you get at another work-spot

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Safety problem

for user readability the font-size was determined "intelligently"; causing a dangerous mismatch between text and image

URF monitor output:
fixed size letters at fixed grid

EV output: scaleable fonts in graphics overlay
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from extrovert diagnostic quality, via image quality, algorithms and load, to extrovert throughput
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Philips operational view
(manufacturing, service, sales)

Customer objectives
diagnostic quality
diagnosis

Application
image quality

Functional
IQ spec
typical case

Conceptual
render engine

Realization

Realization constraints

Cost revisited in context of clinical needs and realization constraints;

note: original threads are significantly simplified
Overview of architecting method

method outline

framework

Customer objectives | Application | Functional | Conceptual | Realization

submethods

+ key drivers
+ value chain
+ business models
+ supplier map

+ stakeholders and concerns
+ context diagram
+ entity relationship models
+ dynamic models

+ use case
+ commercial, logistics decompositions
+ mapping technical functions and several more

+ construction decomposition
+ functional decomposition
+ information model and many more

+ budget
+ benchmarking
+ performance analysis
+ safety analysis and many more

integration via qualities

explore specific details

reasoning

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