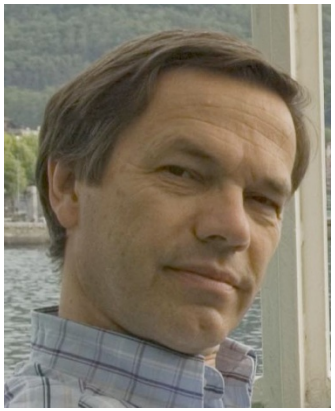
PHILIPS

Embedded Systems in Healthcare

Pierre America
Healthcare Systems Architecture
Philips Research, Eindhoven, the Netherlands
November 12, 2008

About the Speaker

- Working for Philips Research since 1982
- Projects for Philips Healthcare (formerly Philips Medical Systems) since 1996
  - X-ray
  - Magnetic Resonance Imaging
  - Electrophysiology
- Areas of research:
  - Software and system architecting
  - Domain modeling
  - Product families
  - Scenario-based architecting
  - Evolvability



Systems in Healthcare

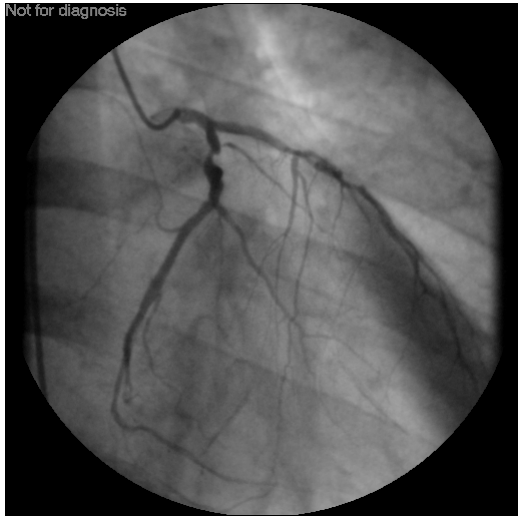
- IT systems
  - Electronic Medical Records (across care providers)
  - Hospital Information Systems
  - Department Information Systems (e.g., cardiology, radiology, …)
  - Picture Archiving and Communication Systems
  - Clinical Decision Support Systems
  - …
- Embedded systems
  - Diagnostic systems
    - Imaging systems
    - Monitoring systems
  - Interventional systems

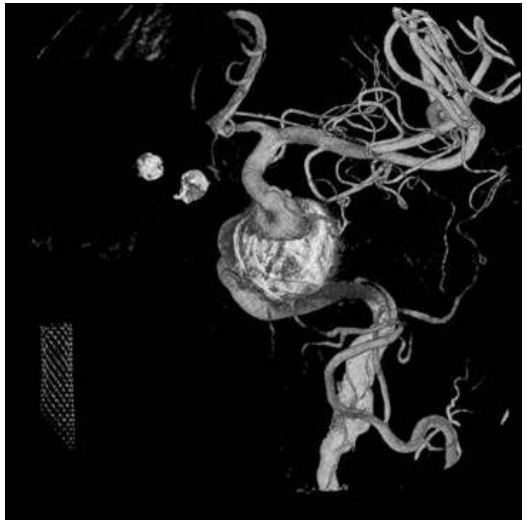
Philips Portfolio

- General X-ray
- Cardio/Vascular X-ray
- Ultrasound
- Computed Tomography
- Magnetic Resonance Imaging
- Nuclear Medicine
- Positron Emission Tomography
- Healthcare Informatics
- Radiation Therapy Planning
- Cardiac and Monitoring Systems
- Home Healthcare

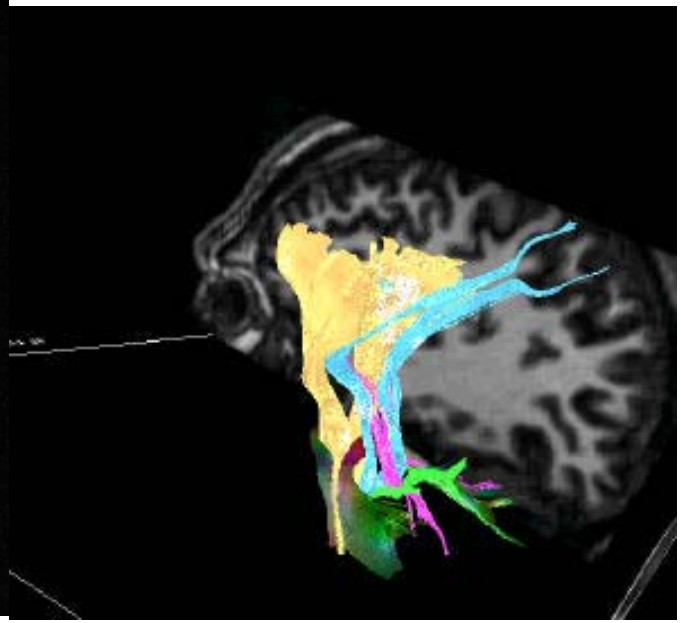
Cardiovascular X-Ray

- Makes images of blood vessels, by subtracting images with and without contrast fluid
- High frame rates needed for cardiology
- Often used in catheter interventions
- Multiple projections needed
  - Biplane saves contrast fluid

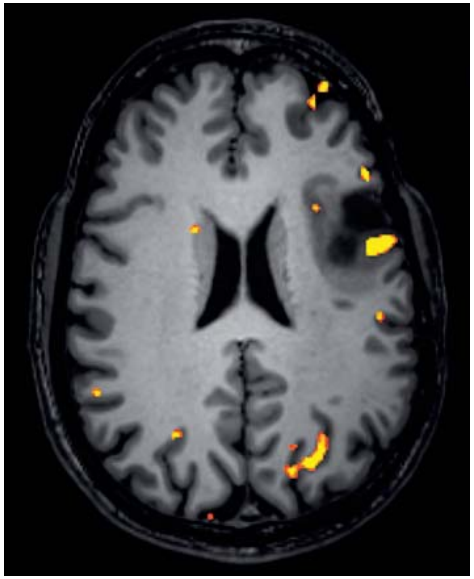




Magnetic Resonance Imaging

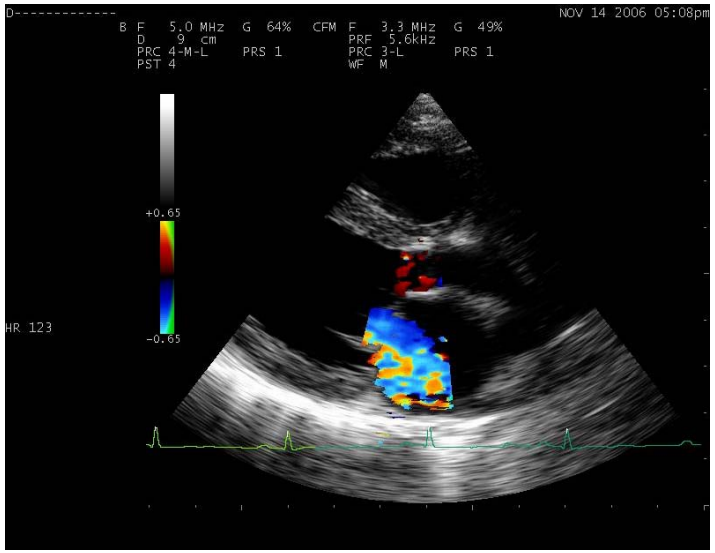


- Measures various parameters: chemical context, density, flow, diffusion, temperature, …
- Useful for soft tissue imaging, e.g., nervous system
- Supports *functional* imaging
- No ionizing radiation



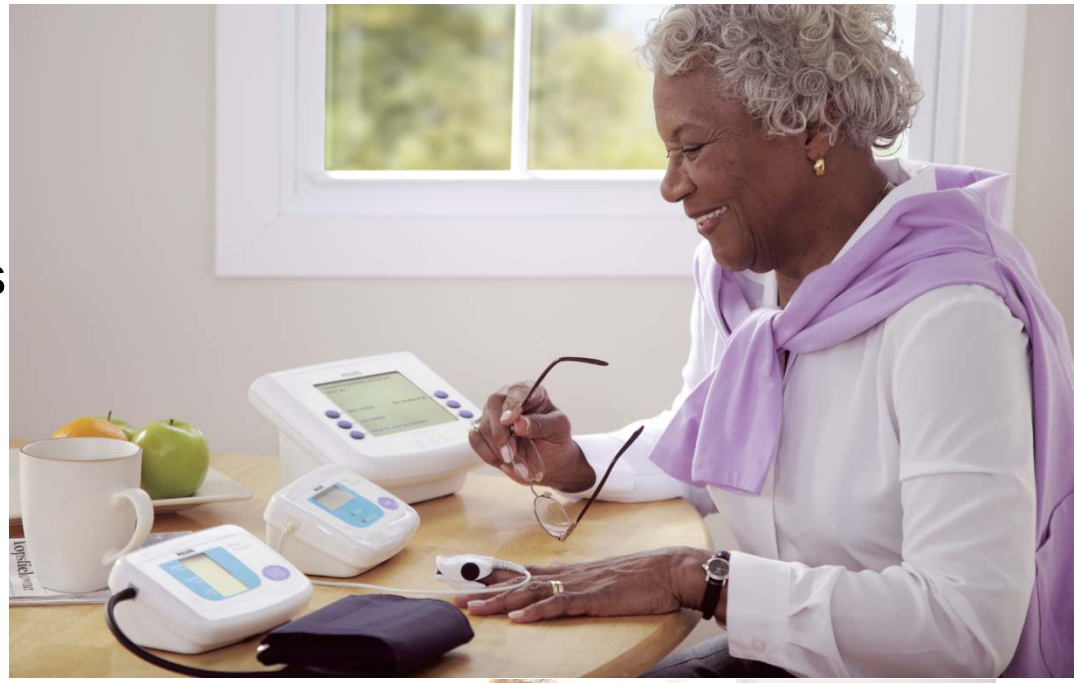
Ultrasound

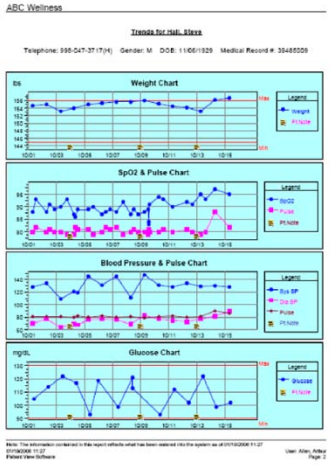
- Most cost-efficient imaging technology
- Wide array of applications
  - Cardiology & Cardiac Surgery
  - Vascular Medicine
  - Obstetrics/Gynecology
  - Radiology

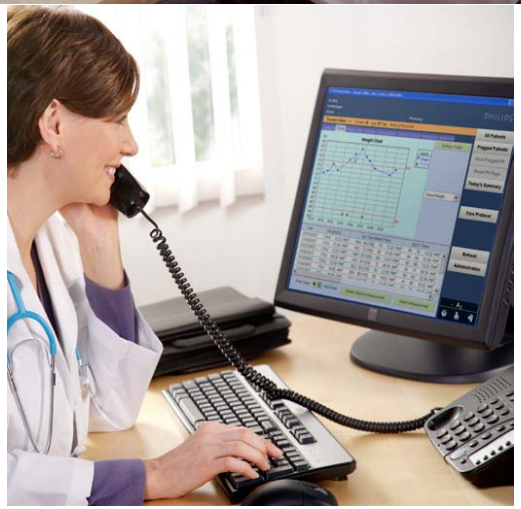


Remote Patient Monitoring

- Measuring devices at patient's home (or even mobile)
- Network connection to service center
- Web-based clinical software to monitor a large number of patients efficiently







Technology Characteristics

- Example: MRI

Programming Languages	C, C++/STL, C#, Visual Basic, ASP, JavaScript, Perl, Batch, and other proprietary languages
Persistent Storage	RDBMS, flat files, indexed and sequential Files, XML
Inter-process communication	Socket, COM, shared memory, shared files
Source Code Size	~8 MLOC in ~30 000 files
Timing accuracy	Scanning hardware: nanoseconds Real-time software: 1 millisecond User interaction: 0.1 – 1 second

Generic Requirements

- Safety
  - Protection from physical hazards:
    radiation, voltage, heat/cold, moving parts
  - Sterizability and resistance to various fluids
  - Avoidance of clinical errors
- Ease of use
  - Easy to learn (not only for experienced radiological operators)
  - Efficient in routine use
  - Optimal support for clinical workflow
- Image and signal quality
  - The best images or signals you can get
  - Easy to control
  - Reproducible
- Connection to clinical infrastructure (HIS, PACS, CDSS, EMR …)

Trends

- Cost reduction
- Feature race
  - Resolution (2D, 3D, 4D)
  - Speed
  - Number of channels, slices, …
- Multimodality
- Imaging aspects: anatomical ➔ functional ➔molecular
- Mixing of control and content:
  Imaging and monitoring systems are more aware of what they see

Challenge: Performance

- Especially relevant for imaging systems
- Data rates are increasing tremendously
- Processing algorithms are getting more sophisticated
  - Removing artifacts (noise, scattering, absorption, movement, …)
  - Image analysis
- Ease of use requirements lead to more advanced user interfaces
- CPU clock speeds are hardly increasing

Challenge: Performance

Response:

- Better performance modeling and optimization
  - High-level models based on measurements
- Parallel computing
  - Graphical cards (SIMD)
  - Multi-core computers
  - Clusters
  - Grid computing

Challenge: Medical Informatics goes Embedded

- The medical world has gathered an enormous mass of knowledge.
- The knowledge is available via a very heterogeneous set of sources:
  - Classifications (SNOMED, ICD, …)
  - Scientific articles/abstracts (PubMed, …)
  - Clinical guidelines (NGC, …)
  - Genomics and proteomics databases (EMBL-EBI, …)
  - Image databases (typically local only, via DICOM)
  - Pathology databases (typically local only)
  - Clinical trials (open to participant organizations)

- Medical equipment is more and more expected to
  - take this knowledge into account
  - make it accessible to its users.

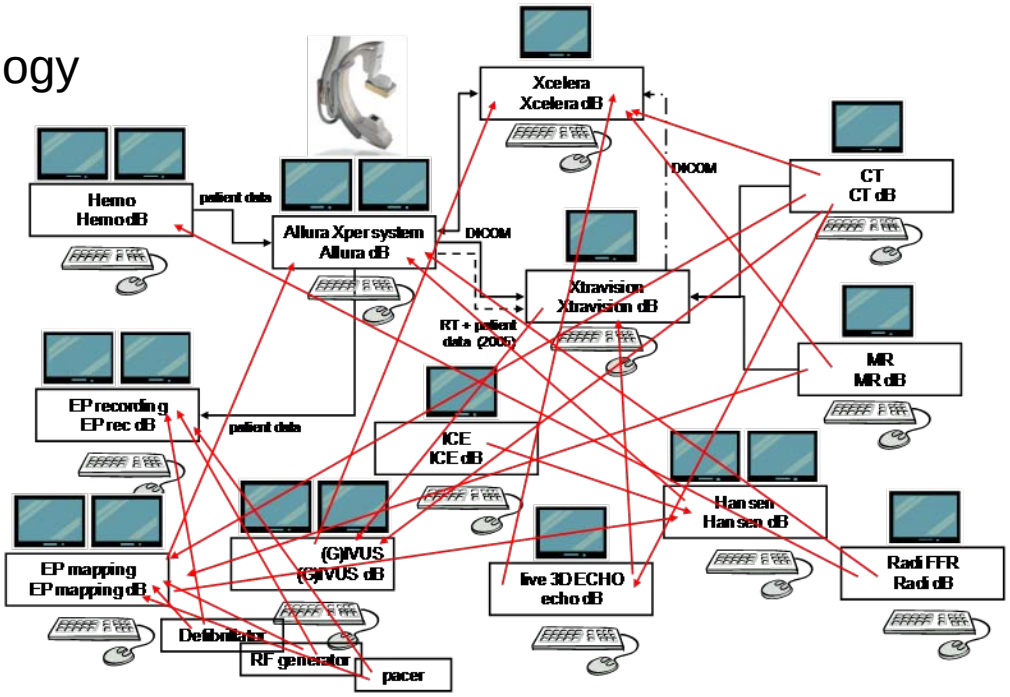
Challenge: Medical Informatics goes Embedded

Responses:

- Medical Informatics
  - Service-Oriented Architectures
  - Data access wrapping/conversion services
  - Ontology modeling and matching
  - Anonymization and pseudonymization services
- Additional for embedded systems:
  - Runtime updating/upgrading

Challenge: Systems of Systems

- Medical systems (almost always) operate in a context of other systems.
- Users expect one integrated system, but currently have to deal with heterogeneous subsystems
  - Catheterization lab
    - Cathlab for electrophysiology
  - Operating room
  - …



Challenge: Systems of Systems

Responses:

- Integration techniques
  - Physical
  - Data
  - Presentation and control
  - Workflow
- Multilevel, heterogeneous modeling
- Analysis and design techniques for robustness

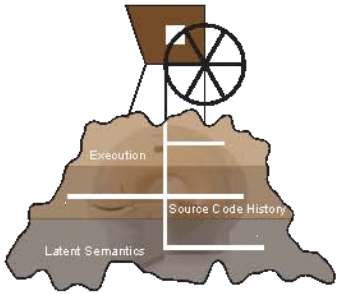
Challenge: Evolvability

- Complexity of systems is high and increasing
  - Inherent complexity
  - Heterogeneity
  - Historical growth
  - Complex multidisciplinary development organization
- Many sources of changing requirements
  - Customer context (clinical applications and workflow, neighboring systems, legislation, reimbursement, …)
  - Technology: generic (operating systems, …) or domain-specific (new MRI gradient amplifiers, solid-state X-ray detectors, …)
  - Business (business model, competition, organization, …)
- Development budgets are not increasing

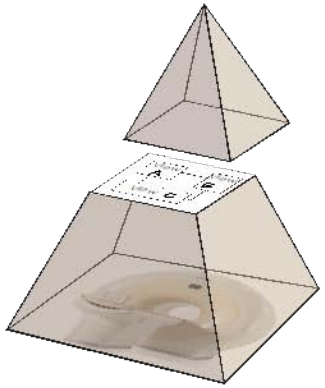
How to adapt to these changing requirements with limited, predictable effort, within limited time, and while maintaining critical quality attributes?

Challenge: Evolvability

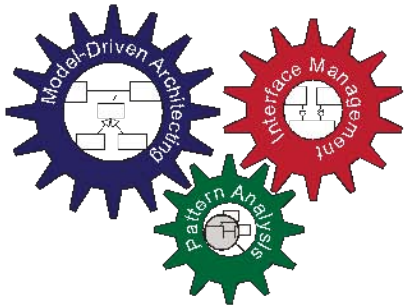
- Responses:



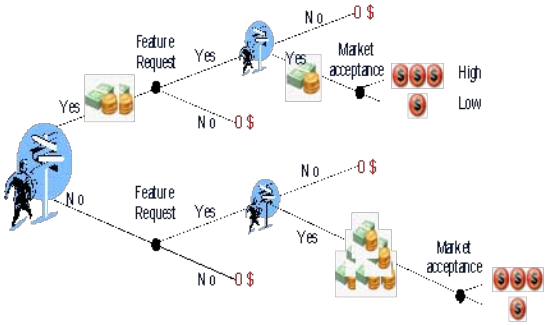
Mining the Existing Realization



Reference Architecture



Mechanisms, Patterns, Guidelines



Economic Decision Making