HPC Programs and Needs @ Philips Research

Sven Prevrhal
Philips Research Hamburg
April 14, 2016 for the 7th INFIERI workshop

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Introduction
Philips Research Hamburg

Sven Prevrhal
Philips Research Hamburg
July 24, 2015

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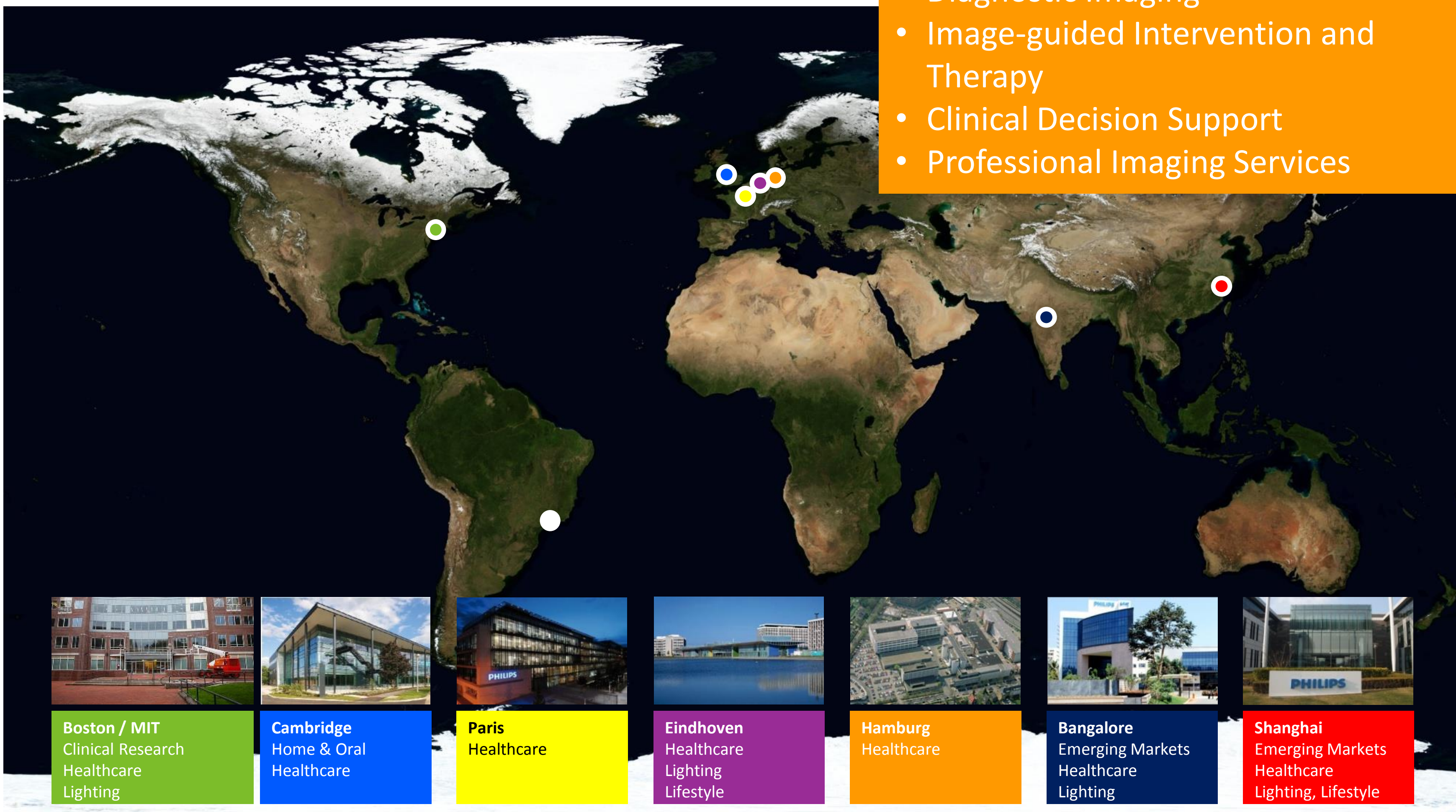
Philips Research

More than 1500 Scientists / Engineers

Philips Research Hamburg

100 Employees
Innovation Areas:

- Diagnostic Imaging
- Image-guided Intervention and Therapy
- Clinical Decision Support
- Professional Imaging Services



Philips Research Innovation Areas and Topics

Healthcare

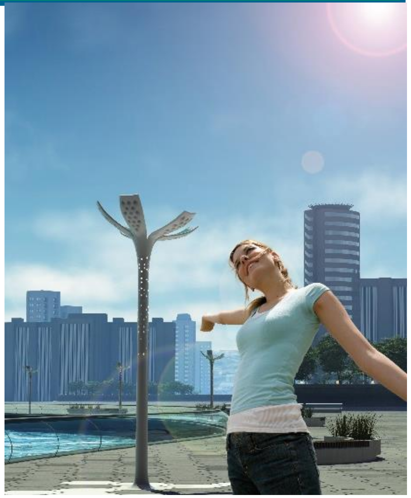
- Diagnostic imaging
- Image-guided intervention & therapy
- Patient care
- Clinical decision support
- Home and personal healthcare
- Healing environments and services

Consumer Lifestyle

- Healthy life
- Personal care
- Home living
- Interactive living

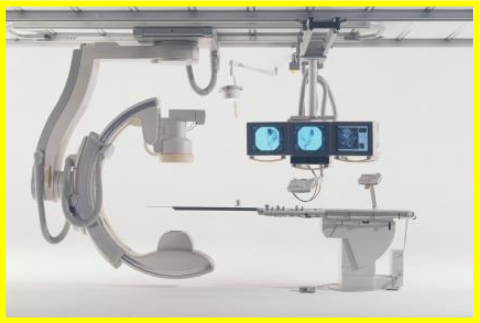
Lighting

- LED conversion and systems
- Advanced light delivery
- Light and energy management
- Lighting services
- Light for Health and well-being



Diagnostic Imaging

Diagnostic X-ray Imaging

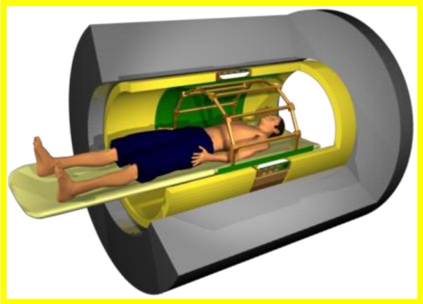


Computed Tomography

Magnetic Resonance

Ultrasound

Hybrid Tomographic Imaging



Magnetic Particle Imaging

IGIT, CDS

Image-guided Intervention & Therapy

Radiation Oncology

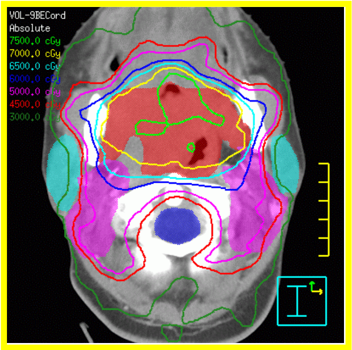
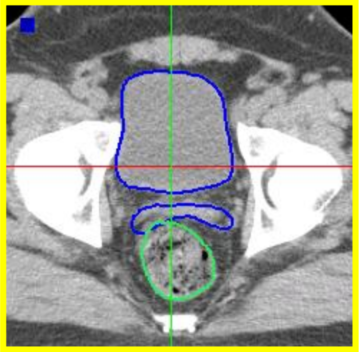
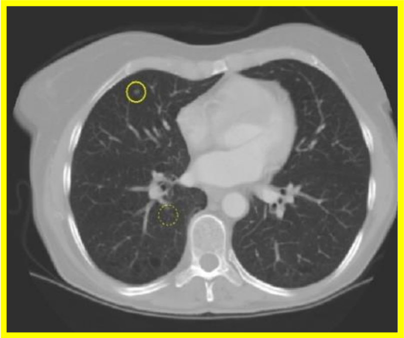


Image Registration / Segmentation / Fusion

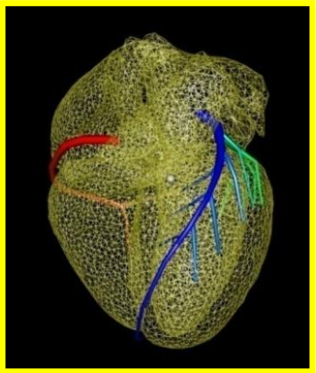


Professional Imaging Services

Computer Aided Detection / Clinical Decision Support



Modeling



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Key Contacts with Universities / Institutes

Univ / Institute	Content
Kings College London	Interventional MR, MR EP, qMRI
NIH, Bethesda	MR Quantification
Johns Hopkins, Baltimore	Interventional X-ray
Charité/DHZ Berlin	Cardiac MR, MPI, CDS for Dementia
U o Wash., Seattle	Cardiac MR, CAD/CDS for Dementia
Univ. Bonn	MR Methodology, Quantification
UKE Hamburg	MPI, Oncology CDS
Univ. Utrecht	MR-RT
Univ. of Leiden	MR Methodology
Univ. Magdeburg	Interventional MR
Univ. of Kyushu	qMRI
Univ. of Lübeck	MPI, MR Methodology
Univ. Clinic Munich	Spectral CT, Phase Contrast CT

Massive Parallel Computing For PET Reconstruction

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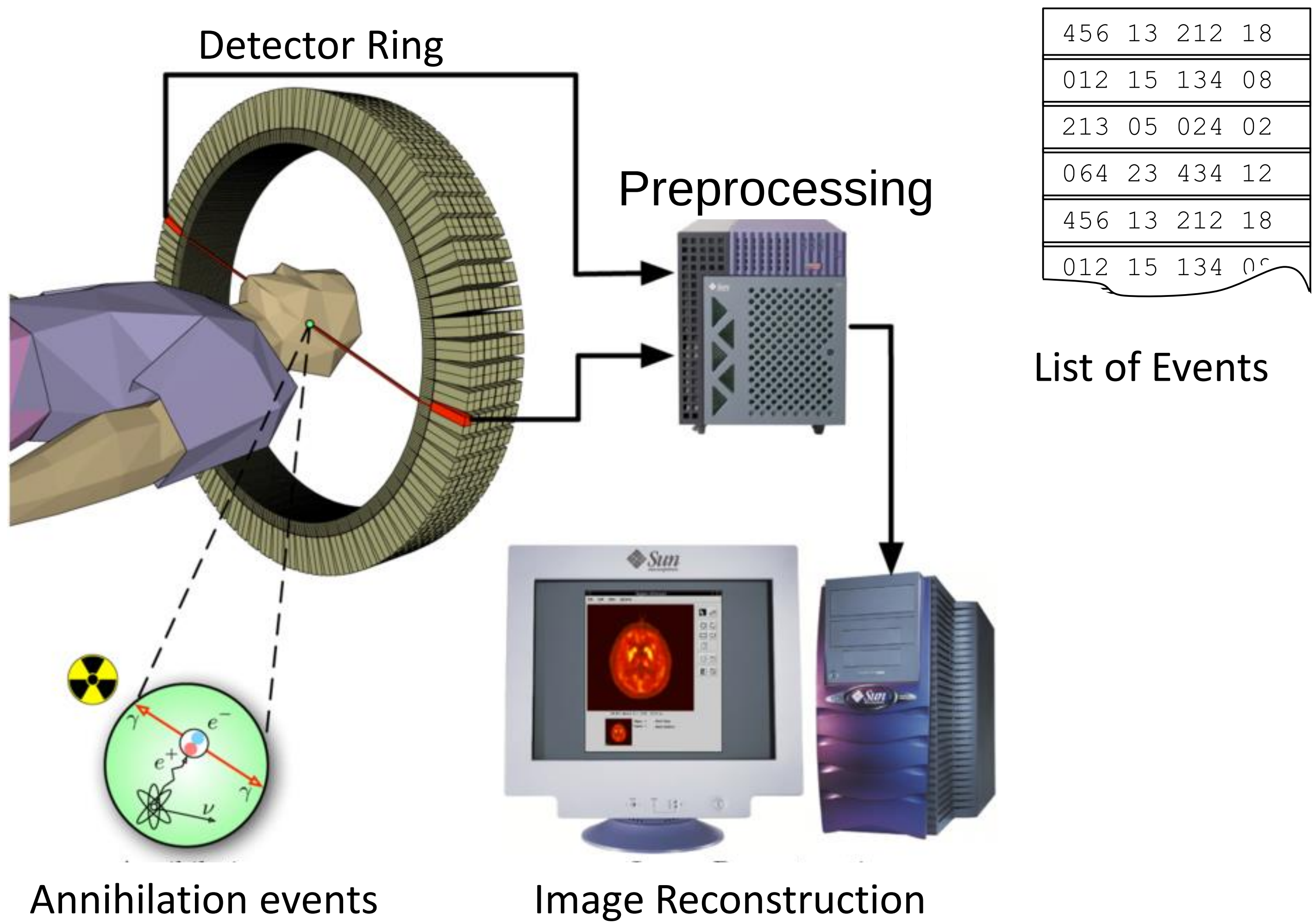
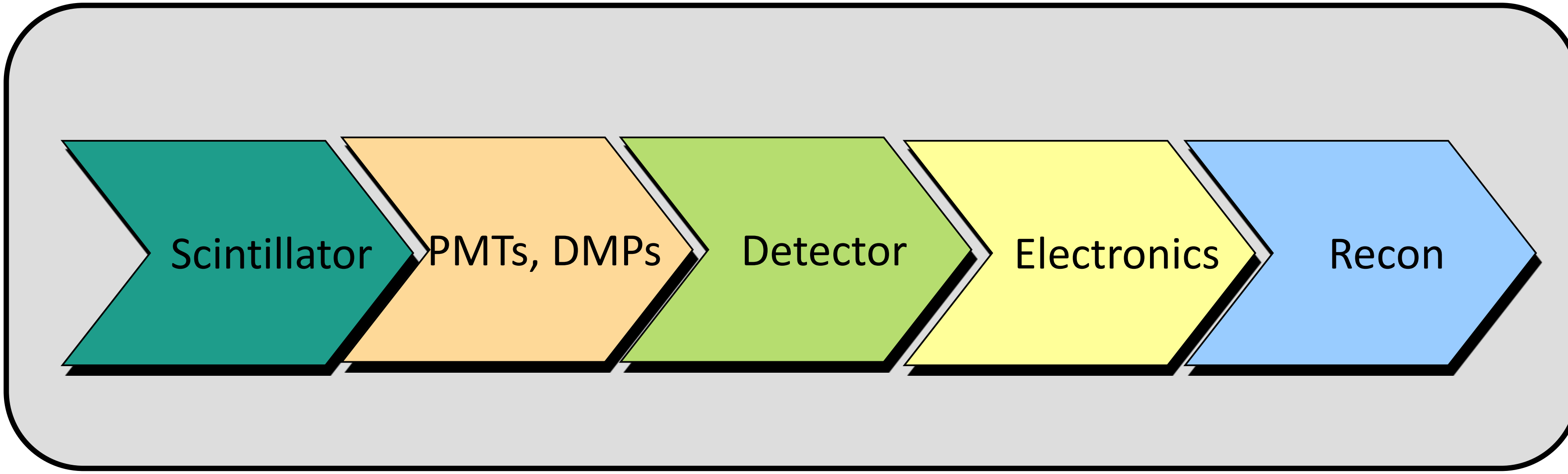
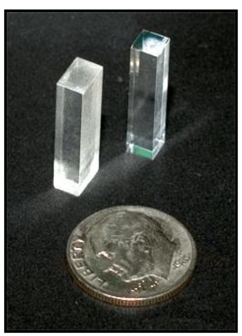
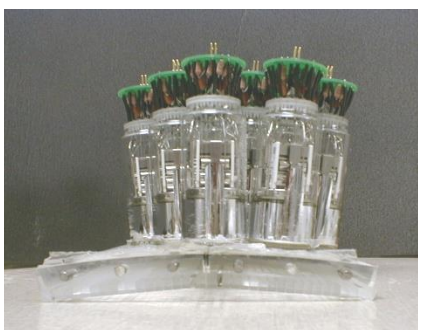
PET- Positron Emission Tomography



PET Instrumentation



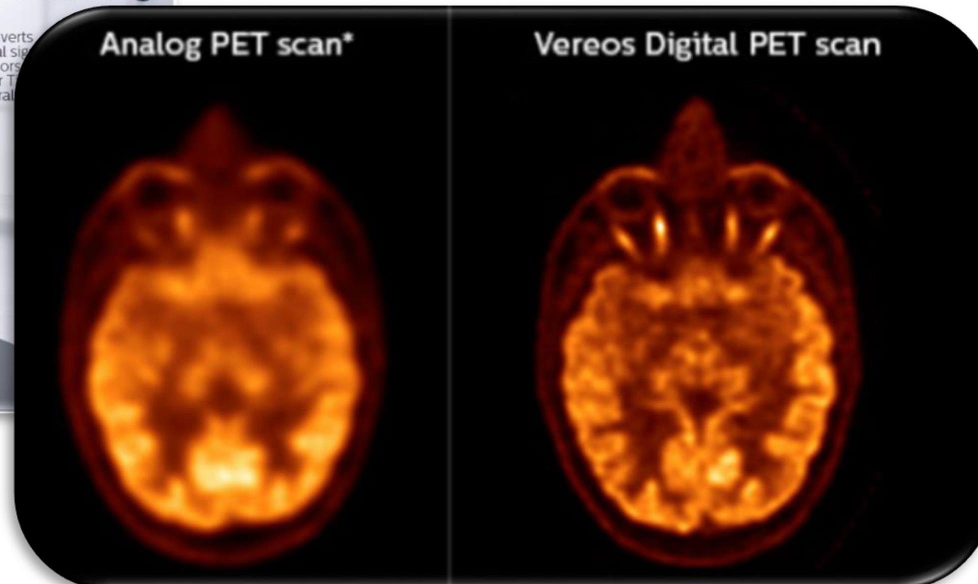


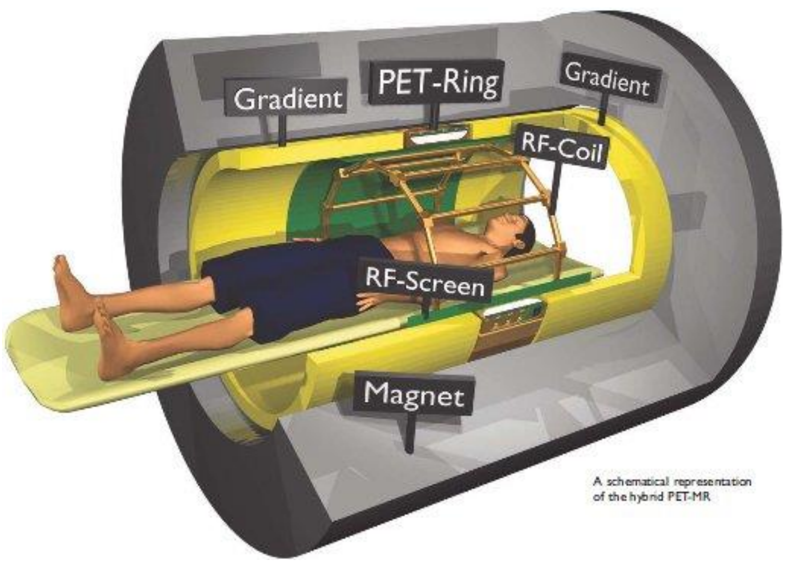


$$\hat{f}_i^{k+1,OSEM} = \hat{f}_i^k \left\{ (1-\lambda) + \frac{\lambda}{s_i} \sum_{j=0}^{J-1} H_{ji}^{objRayWt} H_{ji}^{TOF} \frac{1/(\eta_j^{xtaleff} \eta_j^{decay} \eta_j^{deadtime} \eta_j^{\det geom})}{\sum_{n=0}^{N-1} H_{jn}^{objRayWt} H_{jn}^{TOF} \hat{f}_n^k + \frac{r_j + sc_j(\hat{f}^k, \mu)}{\eta_j^{\det geom} \eta_j^{atten}}} \right\}$$

$$\text{where} \quad s_i = \sum_{\text{all possible } j} \eta_j^{atten} H_{ji}^{objRayWt} H_{ji}^{TOF}$$

PET imaging: Imaging and recent developments





A schematical representation of the hybrid PET-MR

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PET Image Reconstruction

How to turn this:

456	13	212	18	1.2
012	15	134	08	0.8
213	05	024	02	1.4
064	23	434	12	0.6
456	13	212	18	-0.1
012	15	134		.4

List of Events

<u>OSEM</u>

List-**M**ode

Iterative

Ordered-**S**ubsets **E**xpectation-

Maximization Reconstruction

Into this:

PET reconstruction: From events to images

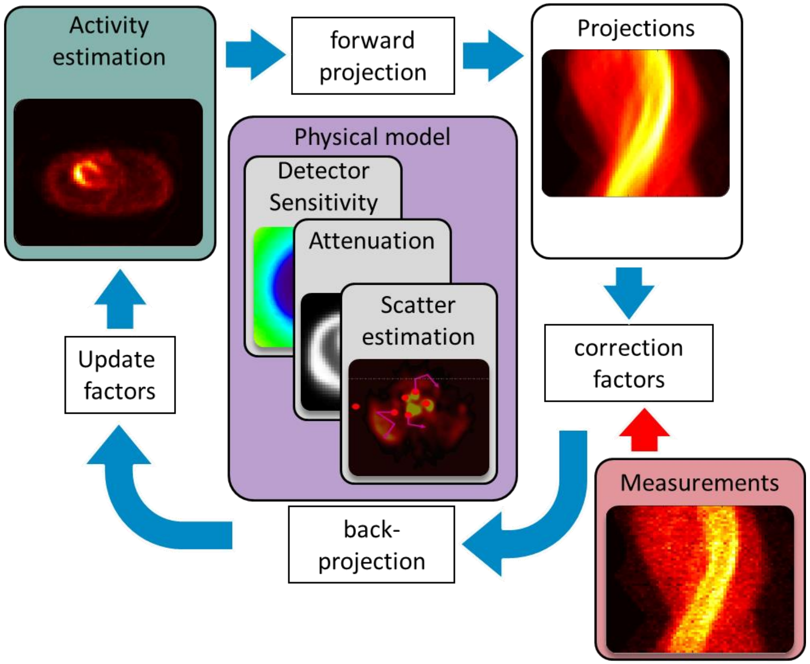
- Reconstruction estimates tracer distribution by optimizing conditional likelihood:

  L (tracer distribution | meas., physical model)

- Physical model considers:
  - Detector setup and geometry
  - Attenuation and scatter in the patient

- Iterative Algorithm for likelihood optimization

$$\lambda_j^{n+1} = \lambda_j^n \cdot \frac{1}{\sum_i a_{i,j}} \cdot \sum_i a_{i,j} \frac{y_i}{\sum_j a_{i,j} \lambda_j^n}$$



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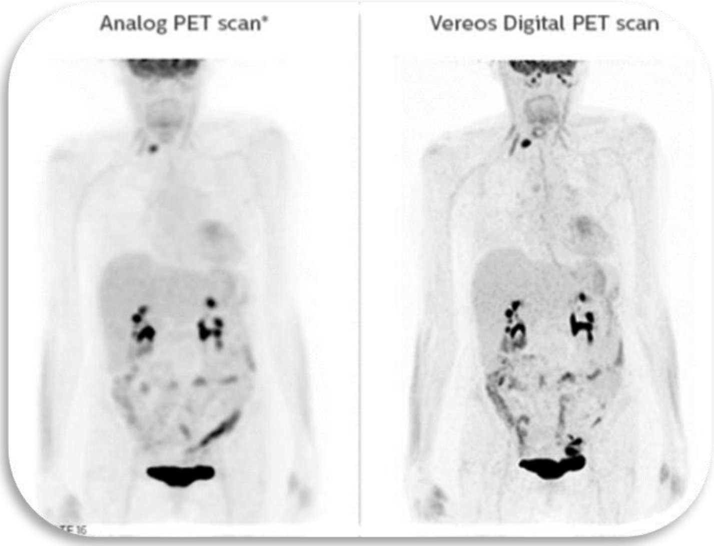
PET reconstruction: Why hurry?



- Computational time constrains by clinical workflow
- Real-Time reconstruction to
  - Guide patient positioning
  - Early detection of imaging issues (e.g. spilled activity)
  - Establish feedback loops (image guided therapy)

Accelerators in medical imaging

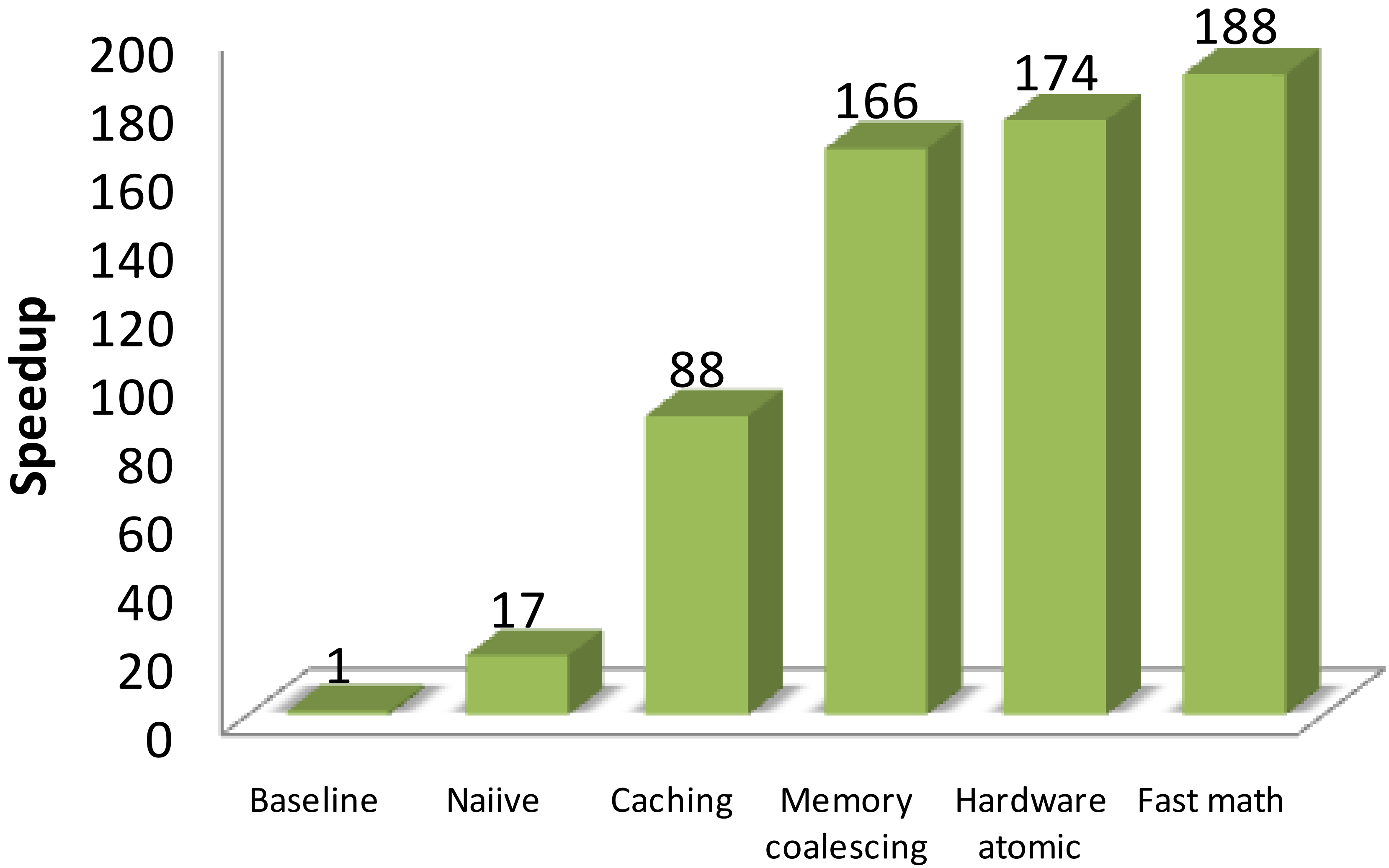
- GPGPUs are used in several imaging modalities and tasks ([1]Cui et al.)
  - Image registration
  - Segmentation
  - Filtering
  - PET/SPECT/CT reconstruction (FBP, MLEM)
  - MR-reconstruction

- PET recon on Xeon Phi with motion correction ([2]Ryder et al.)
  - Focus on time averaged sensitivity map calculation and list-mode MLEM recon motion
  - Found about 0.66 the performance of a dual CPU server
  - Use Workstation with Xeon Phi accelerator instead of high performance server

[1] Cui, J.; Pratx, G.; Prevrhal, S. & Levin, C.S. Fully 3D List-Mode Time-of-Flight PET Image Reconstruction on GPUs Using CUDA, Medical Physics Vol. 38, pp. 6775-6786
[2] Ryder, W. J., et al. "List-mode PET image reconstruction for motion correction using the Intel XEON PHI co-processor." *SPIE Medical Imaging*. International Society for Optics and Photonics, 2014.

GPGPU

Breakdowns of the speedup



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Credits

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Thomas Köhler
Dirk Schäfer

Research and Engineering

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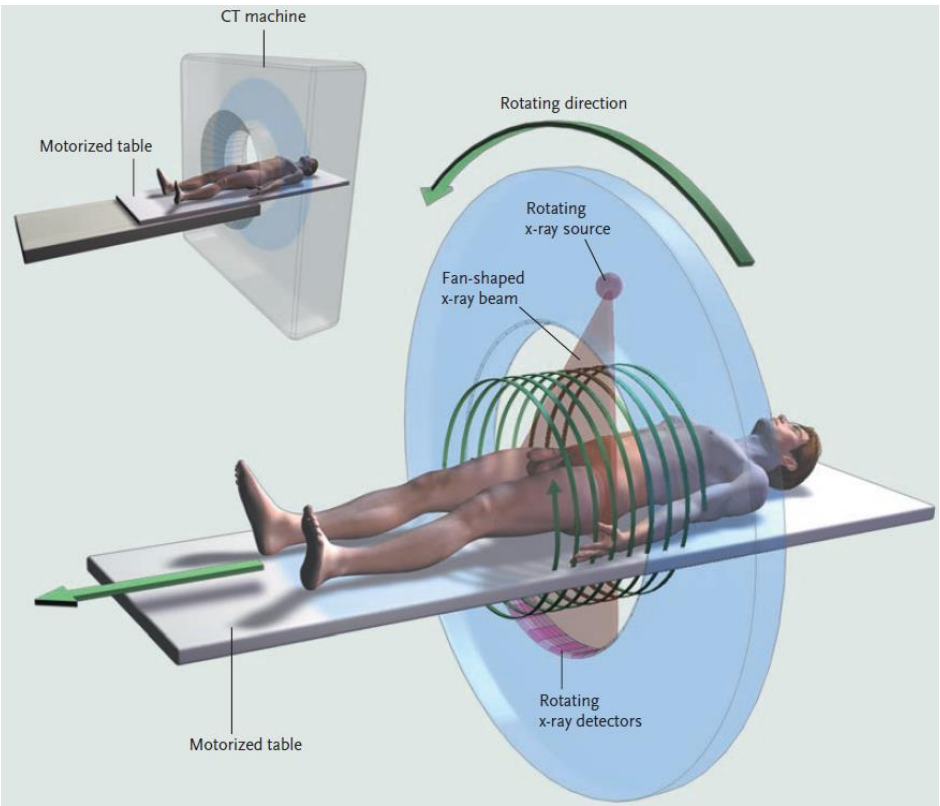
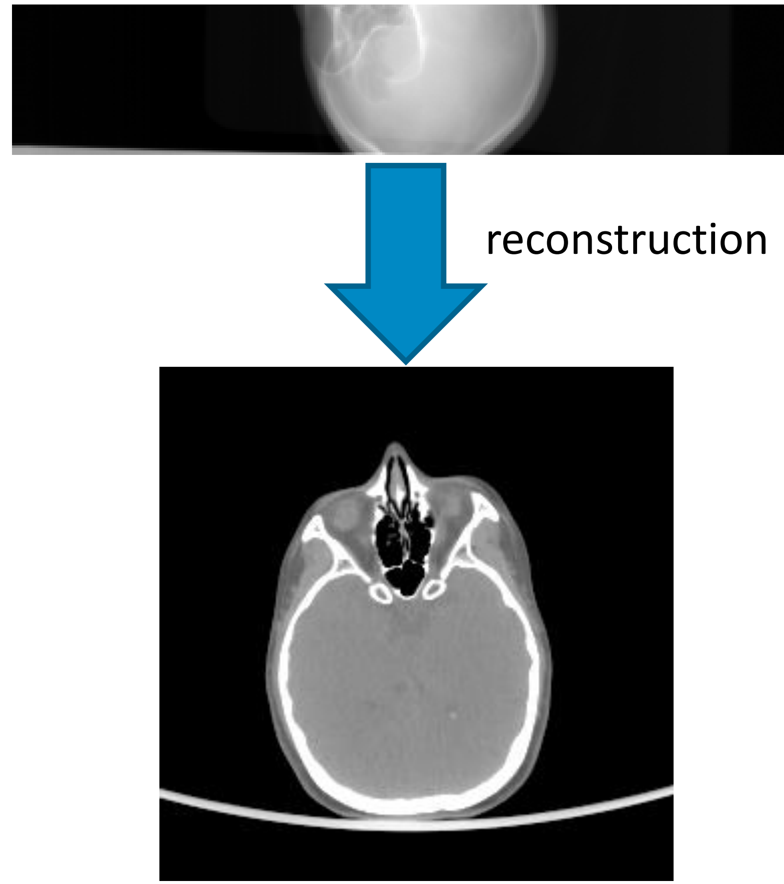
HPC in CT and Cone-Beam CT

Thomas Köhler
Philips Research Hamburg

X-Ray Computed Tomography





Reconstruction as Large-Scale Optimization Problem

image
typical 0.5
Giga-Samples

projection data
typical 2 Giga-
Samples

Regularization
parameter

$$\hat{\mu} = \operatorname{argmax}\left(L(\mu, p) - \beta R(\mu)\right)$$

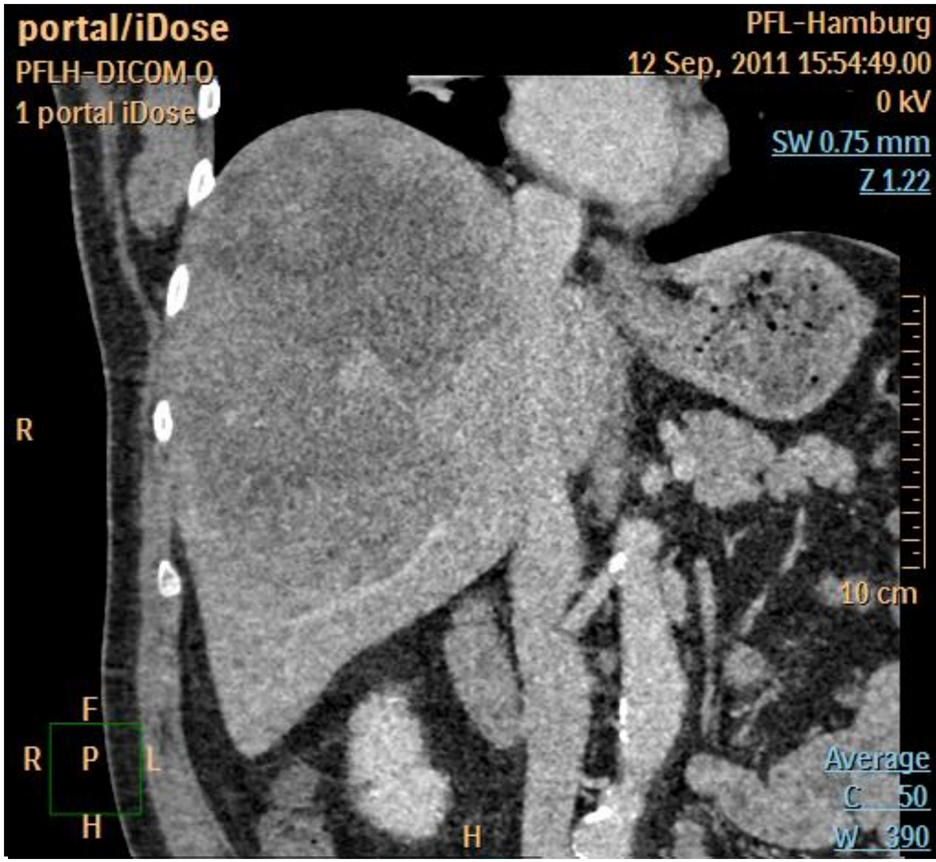
Likelihood of image
“data term”

required accurate modeling of data acquisition

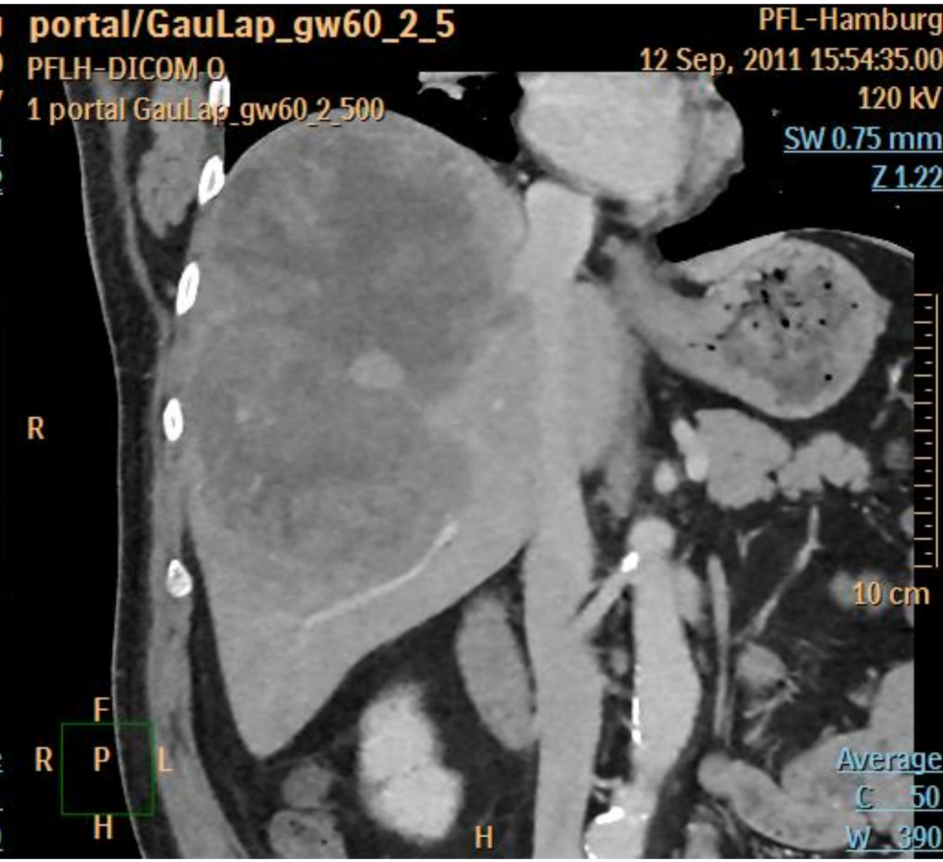
Roughness penalty
“model term”

Example Reconstruction – Conventional CT

analytic reconstruction



maximum likelihood reconstruction



New Trend – Dual Energy CT

- input data size doubles
- output data size doubles
- physics to be modeled is more complicated
- => high performance computing required

Photo analytic reconstruction

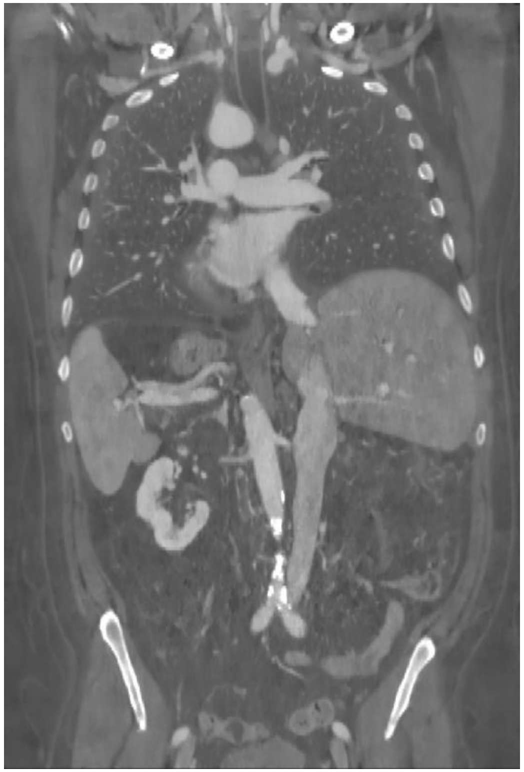


Photo maximum likelihood reconstruction

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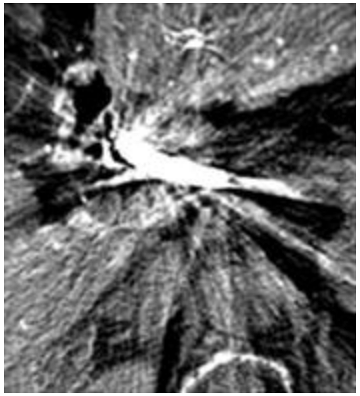
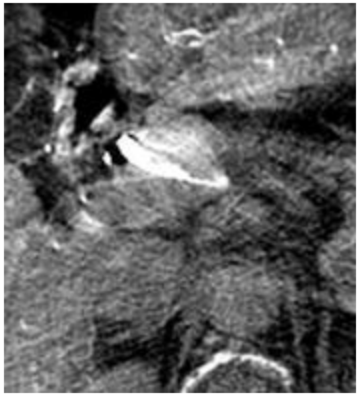
Motion and metal: Two problems in Computed tomography

- Existing multi-pass algorithm addressing both problems simultaneously.
- Implemented on multi-threaded CPU.
- Acceleration on GPU needed.
- Interesting problem, because not all processing steps can be translated directly to massively parallel processing.





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