PET Image Reconstruction Cluster at Turku PET Centre

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Turku PET Centre
University of Turku

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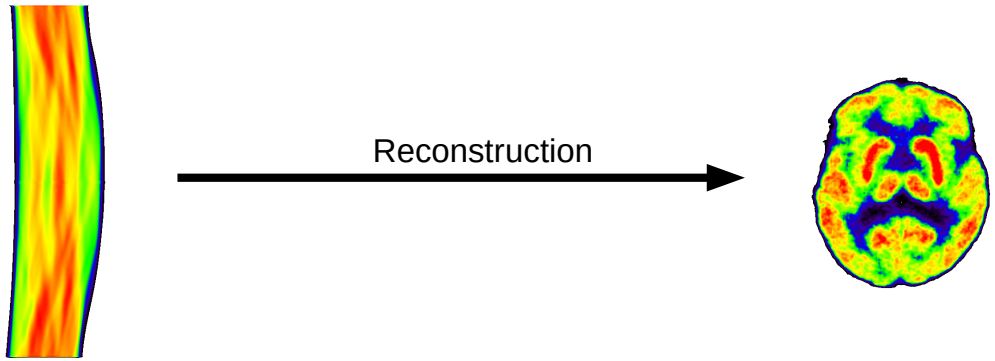
Outline

Image Reconstruction from Projections.

- General reconstruction problem: transform the acquired sinogram data to human readable image data



Acquired sinogram data

Reconstructed image data

- The reconstruction problem is theoretically equivalent to finding the inverse *Radon transform* of $g(s,\theta)$

$$g(s,\theta) \triangleq \mathcal{R}f = \iint_{\mathbf{R}\times\mathbf{R}} f(x,y)\delta(x\cos\theta + y\sin\theta - s)\,dx\,dy.$$

- The inverse Radon transform is estimated with analytical (e.g. 2D/3D FBP) and statistical (e.g. 2D/3D OSEM) methods

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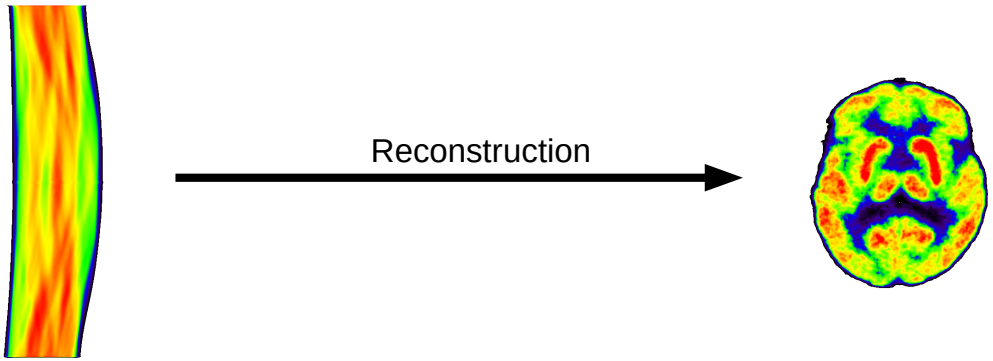

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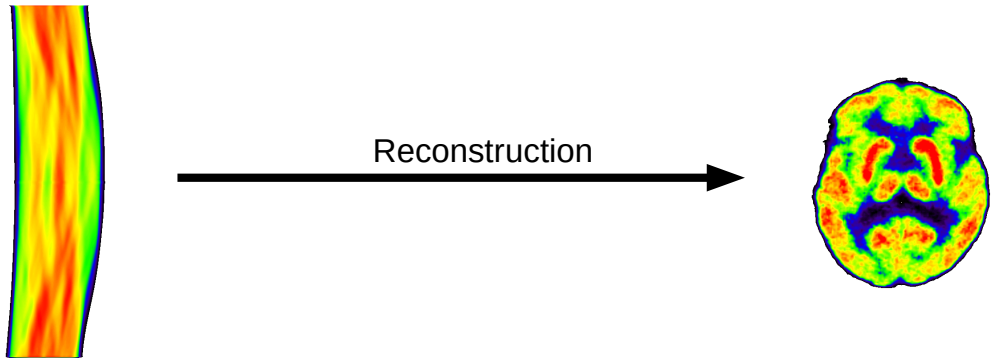

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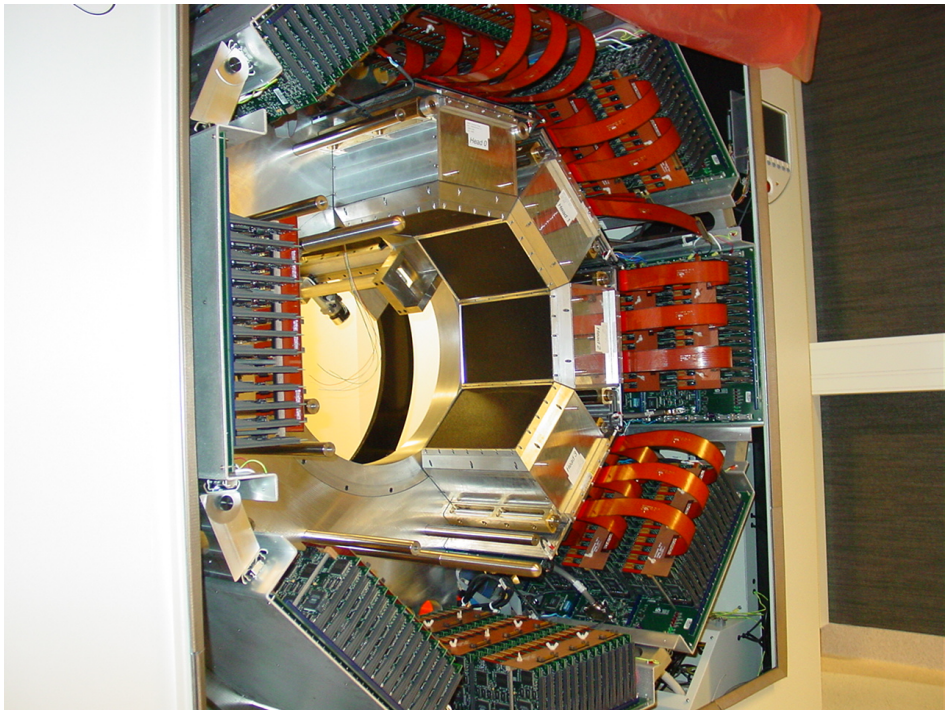
The High Resolution Research Tomograph (HRRT).



- 3D acquisition (no septa)
- Octagonal design
  - 8 flat panels
  - 9×13 blocks in each panel
  - 8×8 crystals in each block

    $\Longrightarrow$ 119808 detectors

    $\Longrightarrow 4.5 \times 10^9$ LORs
- FOV
  - length 25.2 cm
  - head to head distance 46.9 cm

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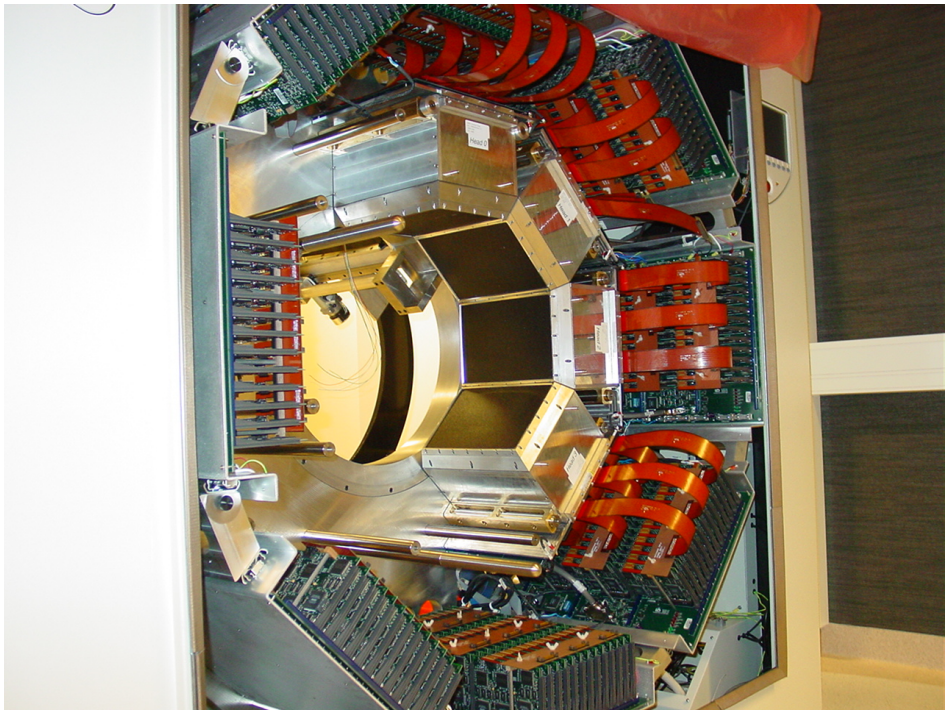

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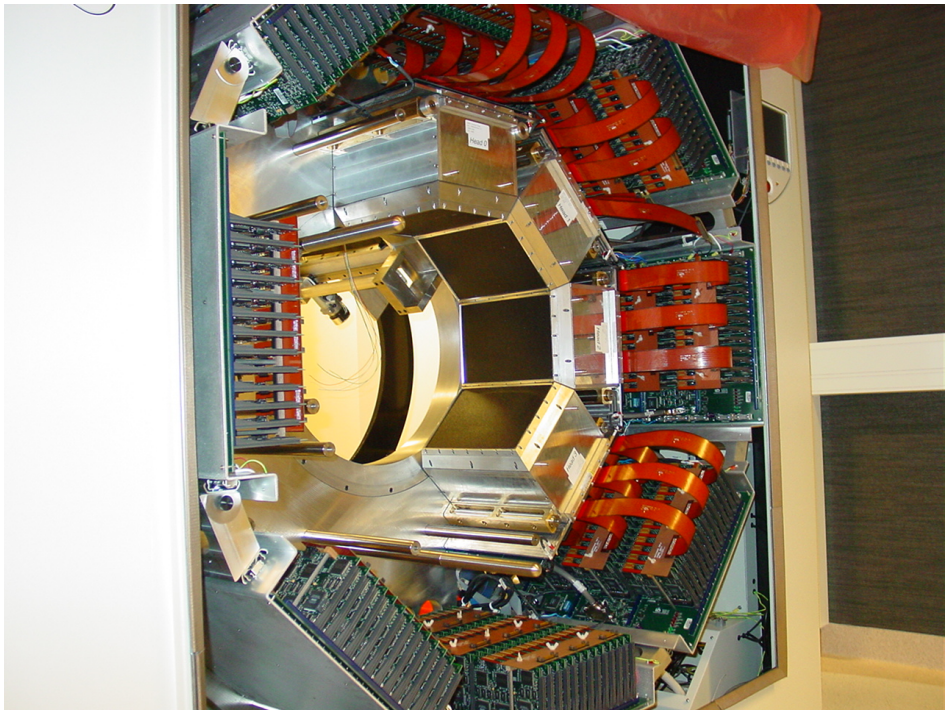

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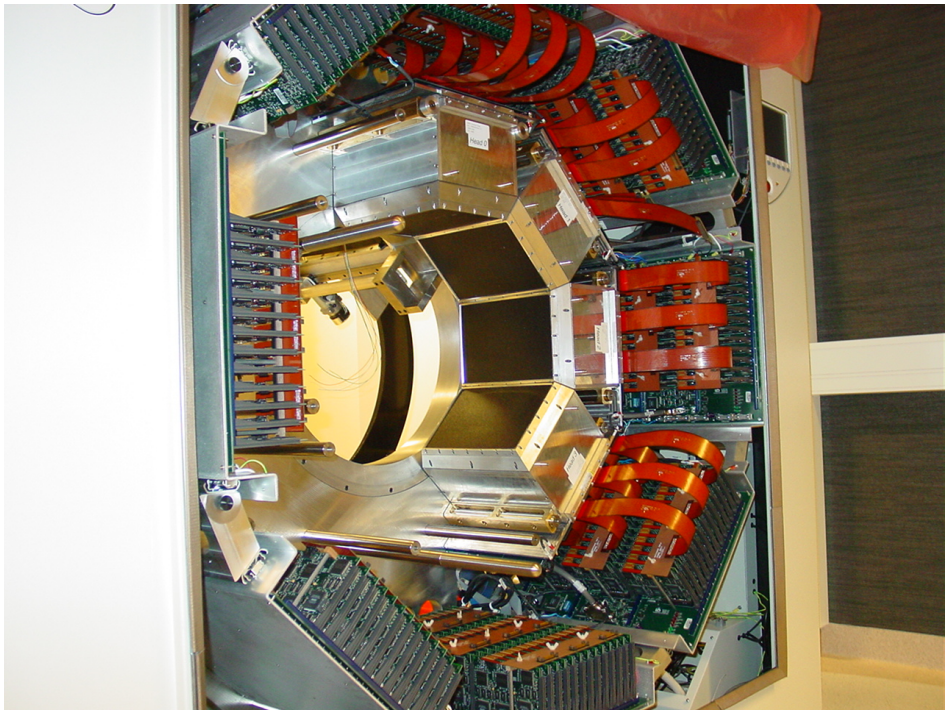

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Reconstruction Problem on the HRRT.

Challenges:

- Data size (in normal mode i.e. RD 67 and span 9)
  - 2209 sinograms with 256 radial elements and 288 views
    $\approx 50\times$ the data size of the GE Advance in 2D mode
  - 311MB/frame of emission data
  - 52MB/frame of image data
- Reconstruction times of span 9 data on a standard processor PC

Per frame calculations	SCF calculation	FORE + 2D-OSEM	3D-OSEM
Time	$\sim$ 8min	$\sim$ 15min	$\sim$ 3hrs 30min

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Challenges (continued):

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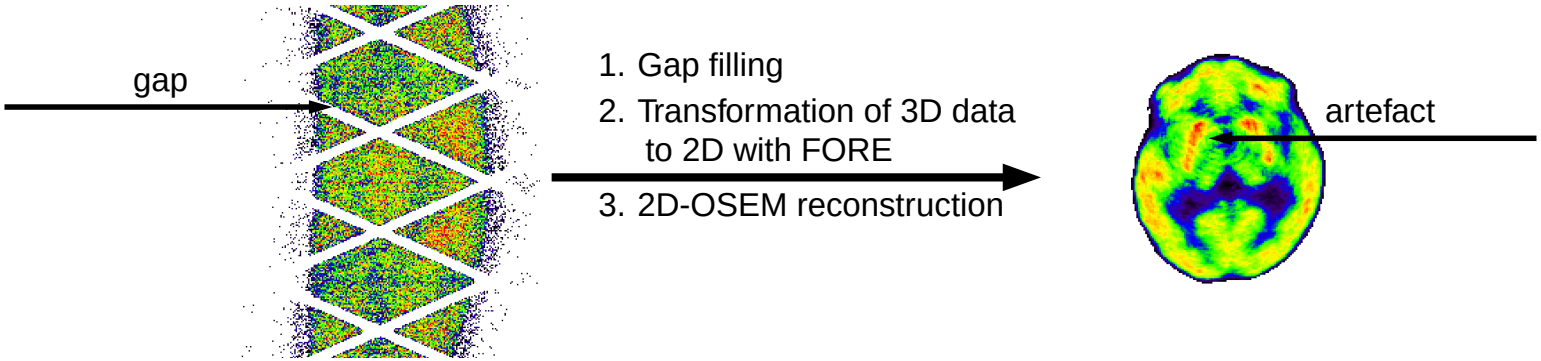

HRRT sinogram data

FORE reconstructed image data

Conclusion:

1. 3D-OSEM reconstruction on a standard processor PC is too time consuming
2. Single high performance processors are extremely expensive
3. FORE with gap filling does not produce satisfactory images

$\Longrightarrow$ Parallelize 3D-OSEM reconstruction for a cluster of standard processor PCs

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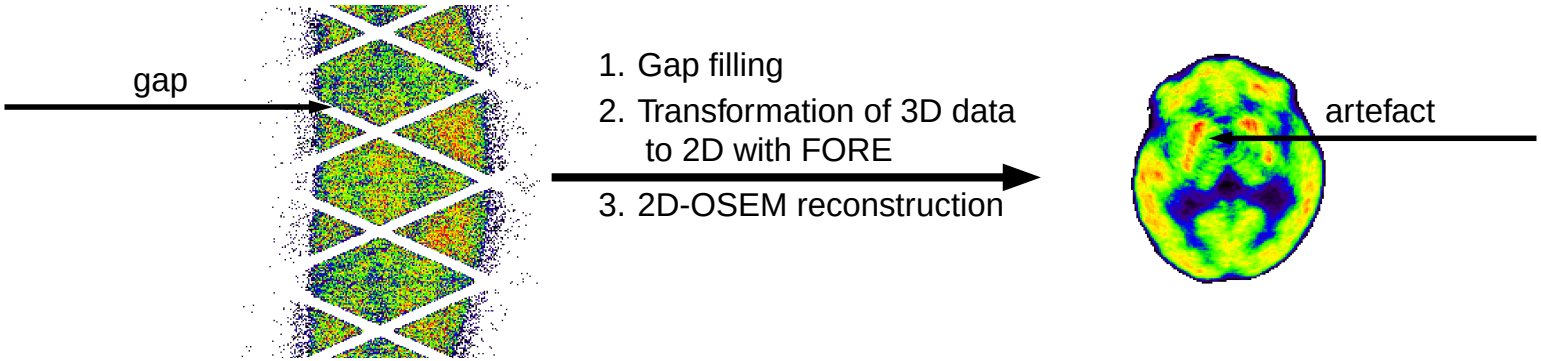

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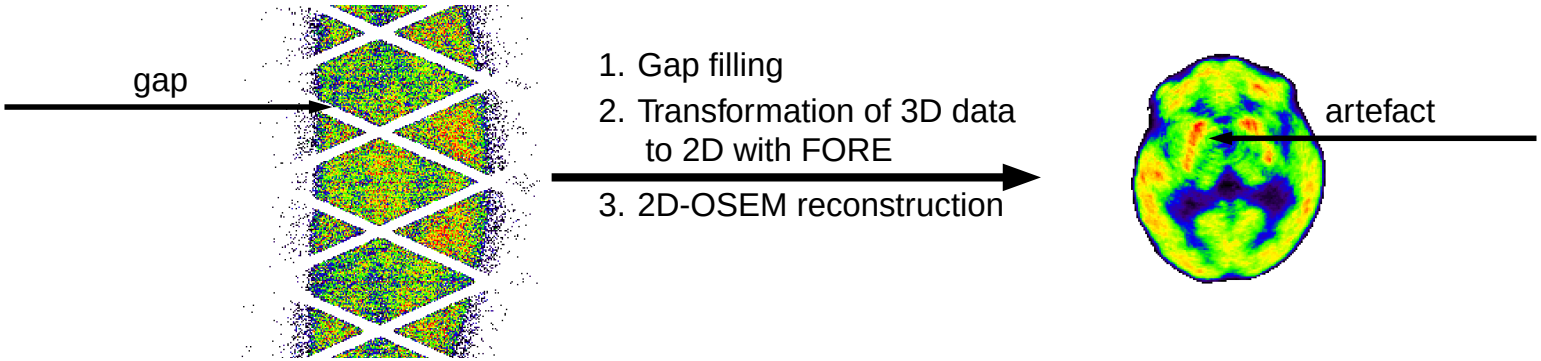

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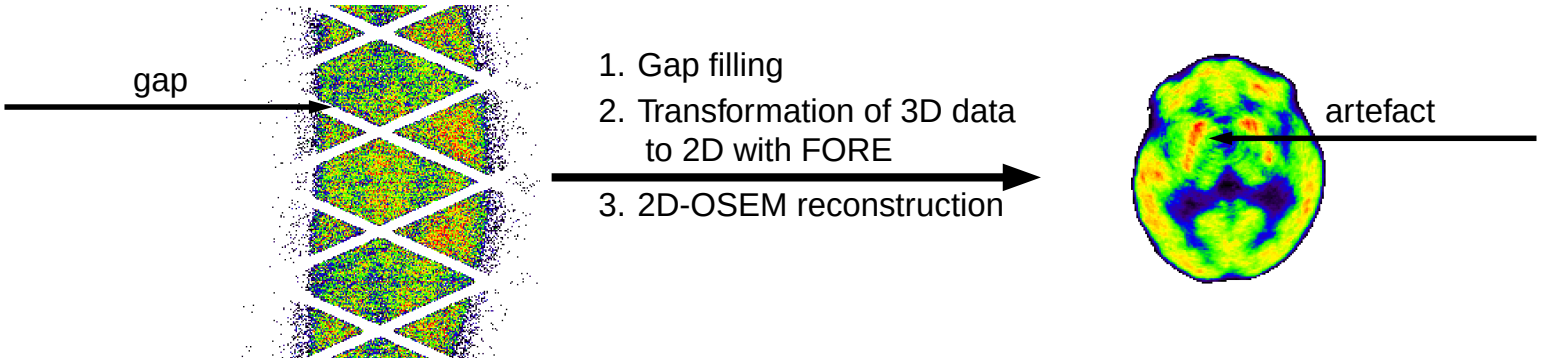

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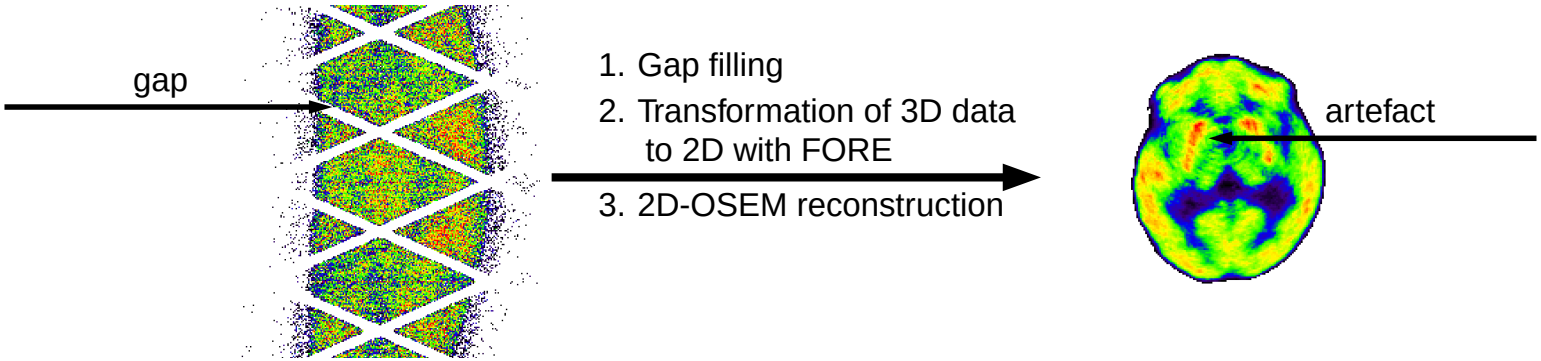

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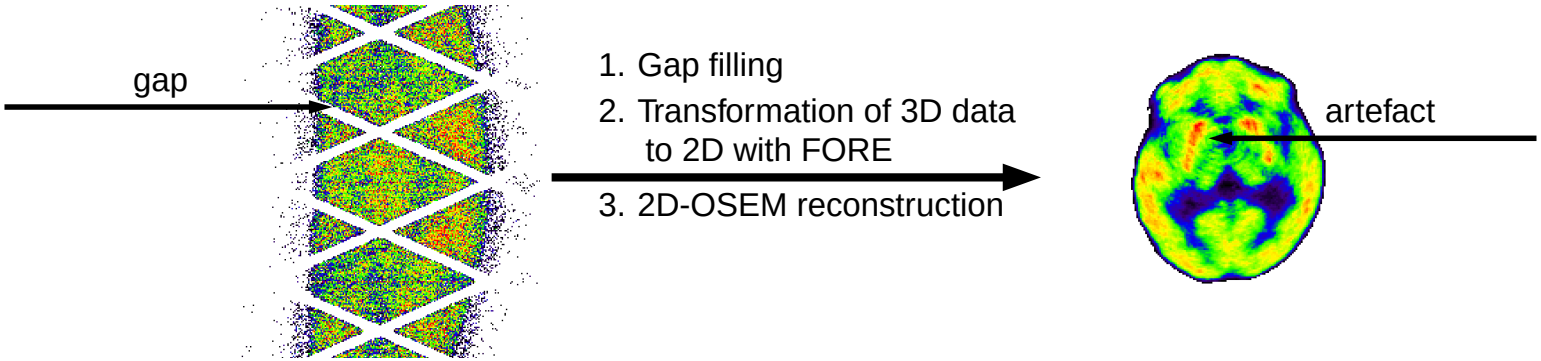

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Description of Parallel Computing.

A computer system in which interconnected processors perform concurrent or simultaneous execution of two or more processes.

Methodical design of parallel programs

- Partitioning
  - decomposing the computation and the data describing the problem into small tasks
- Communication
  - defining the communication that is necessary between the tasks in order to solve the problem
- Agglomeration
  - grouping the tasks together to larger units to achieve sufficient locality in the tasks
- Mapping
  - deciding how tasks are placed onto physical processors

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Parallelization of the 3D-OSEM Reconstruction.

CTI Solution: Two designs.

1. Projection Space Decomposition (PSD)
   - Partitioning and agglomeration
     - each node has a complete local copy of the image volume
     - each node has $1/N^{th}$ of the projection space data
     - computation is decomposed in the projection space
       $\rightarrow$ computations require no interprocessor communication
   - Communication
     - local copy of the image volume is synchronised with all the other nodes in the end of every subset; i.e. 52MB $\times(N-1)$ packets to send and receive

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Parallelization of the 3D-OSEM Reconstruction (cont.).

2. Image Space Decomposition (ISD)

- Partitioning and agglomeration
  - a round-robin method assigns parts of size P of the image and projection space data to each node
  - computation is decomposed in the image space
    $\rightarrow$ part of the computation (back projection) is done only for the assigned part of data
- Communication
  - interprocessor communication with $G << N$ nearest nodes is required after each computation step (forward projection)
  - local copy of the image volume is synchronised with G nodes in the end of every subset

Comparison: the performances of the two models are indistinguishable.

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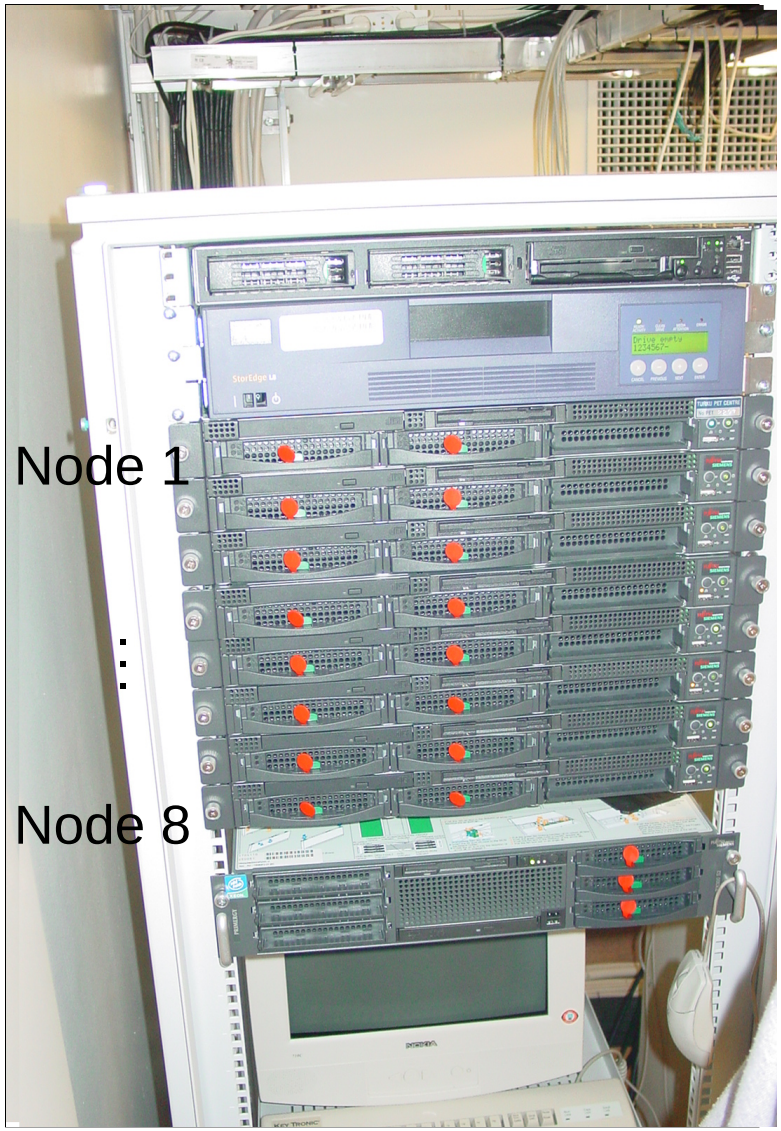
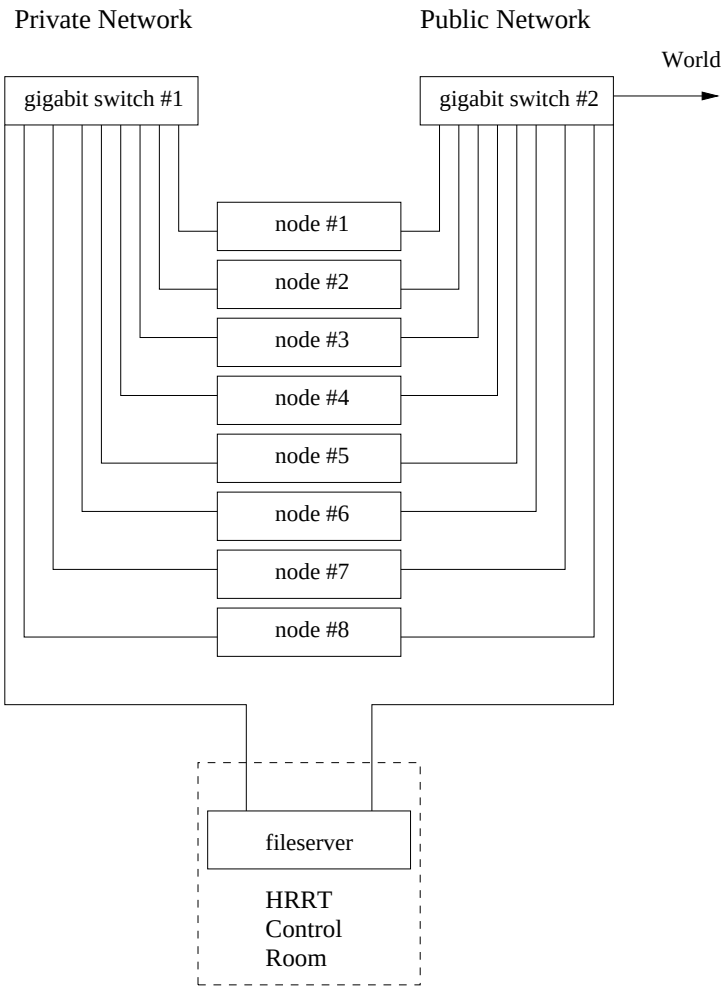
Reconstruction Cluster at Turku PET Centre (Hardware).



- 8 Fujitsu-Siemens RX200 Primergy computing nodes
  - 2 Intel Xeon 3.06GHz CPUs
  - 2GB of RAM
  - 2 mirrored 36GB SCSI disks
  - 2 gigabit ethernet interfaces
- 1 Sun Microsystems SE3510 700GB disk array
- 2 gigabit ethernet switches

Reconstruction Cluster at Turku PET Centre (Software).



- Cluster
  - Operating system Windows XP Pro
  - Parallel 3D-OSEM reconstruction software by CTI; implements ANW and ordered poisson (OP) weighting
- Fileserver
  - Operating system Windows XP Pro
  - Reconstruction toolset with GUI (CTI)

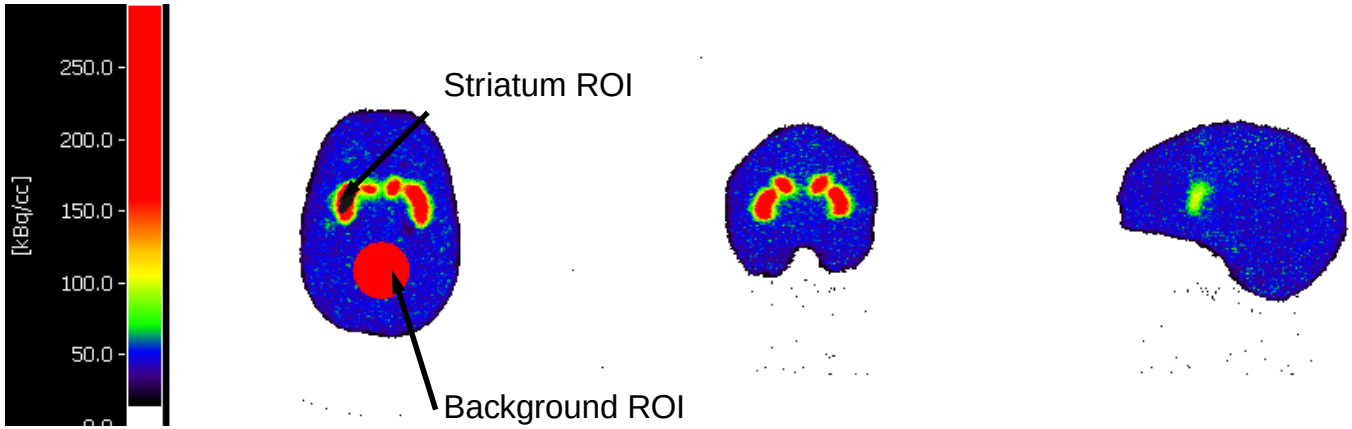
Assignment of reconstruction jobs and queueing to the cluster is embedded in the CTI reconstruction tool.

Results: speedup.

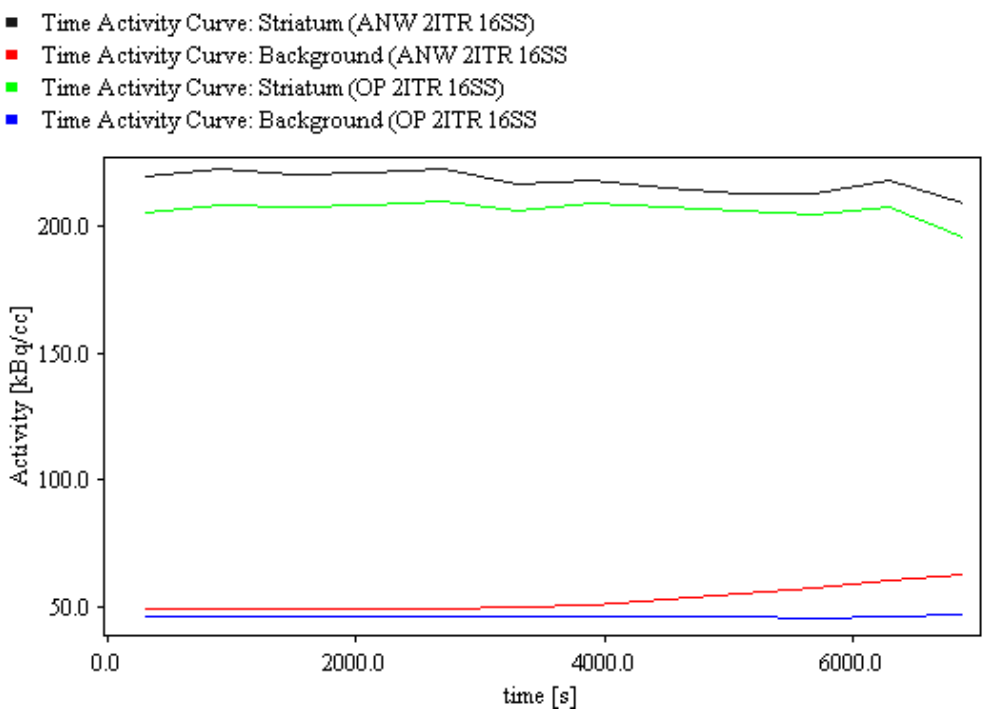
Reconstruction time is reduced to $\sim$ 10 minutes per core iteration, i.e. $\sim$ 30 minutes per frame.

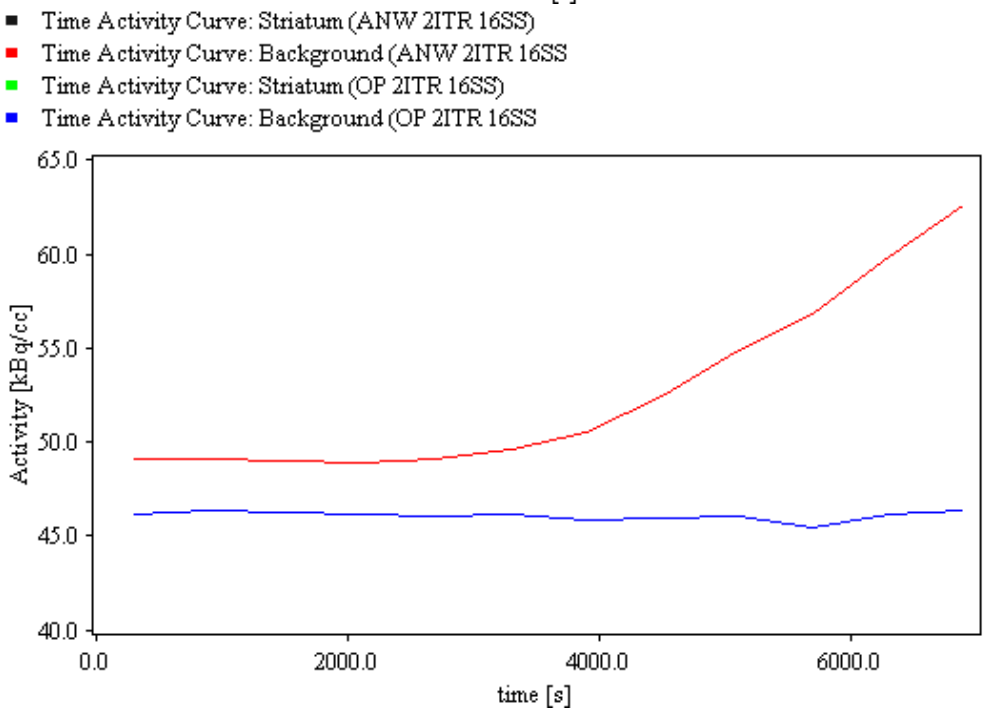
- The measured speedup of 7 correlates nicely to the number of cluster nodes 8
- A 16 node cluster has been tested at CTI, and shown to be cabable to almost linear speedup

Results: images.



- First calibrated cluster images
- Striatum phantom filled with ^{11}C, 21 MBq in the background and 147 MBq in the structures
  $\rightarrow$ 47.5 (kBq/cc) in the background and 218.7 (kBq/cc) in the structures measured with Wizard
- Two hour scan histogrammed to 12, 10 minute frames
- Reconstructed with parallel 3D-OSEM with ANW and OP weighting schemes, both with 2 iterations and 16 subsets





- Activity, both in the striatum and background are slightly overestimated
- OP-OSEM uses smoothing prior to randoms correction $\rightarrow$ performs better in low statistics

Discussion

[Discussion here.]