STIR

Software for Tomographic Image Reconstruction

http://stir.sourceforge.net

Kris Thielemans

University College London
Algorithms And Software Consulting Ltd

Forthcoming release

- OPENMP support
  - Gradient-computation for projection-based reconstruction
  - Full projections
  - Scatter simulation
- Script for iterative scatter estimation
- Siemens mMR support
- Maximum Likelihood estimation of normalisation factors and randoms for PET
- Some improvements to MATLAB/Python interface

STIR

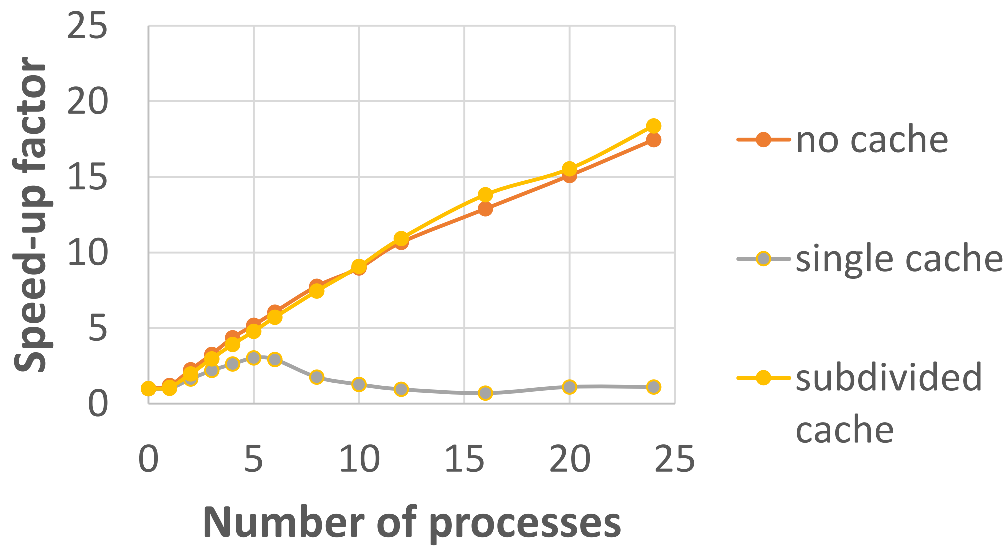
Multi-threaded image reconstruction of 3D PET sinogram data with STIR

Kris Thielemans[1], Vesna Cuplov[1], Benjamin A Thomas[2]

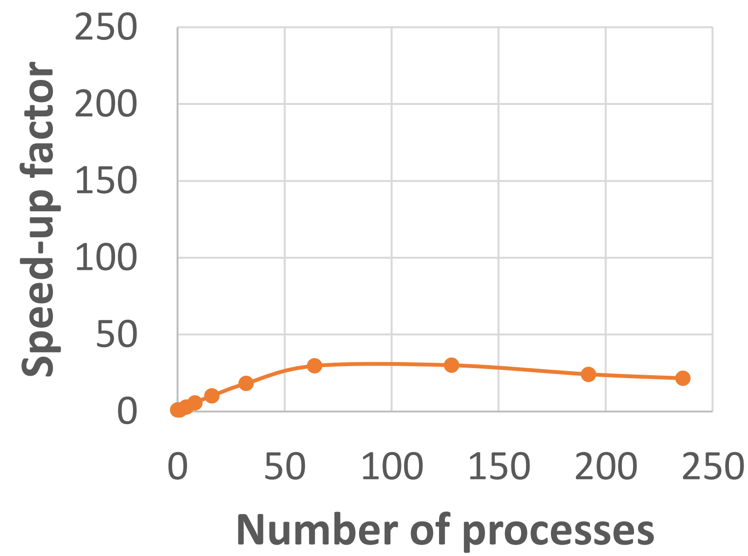
1.Institute of Nuclear Medicine, UCL, UK

2.A*STAR-NUS Clinical Imaging Research Centre, Singapore.

Dual-Opteron system



Intel Xeon Phi 5110P

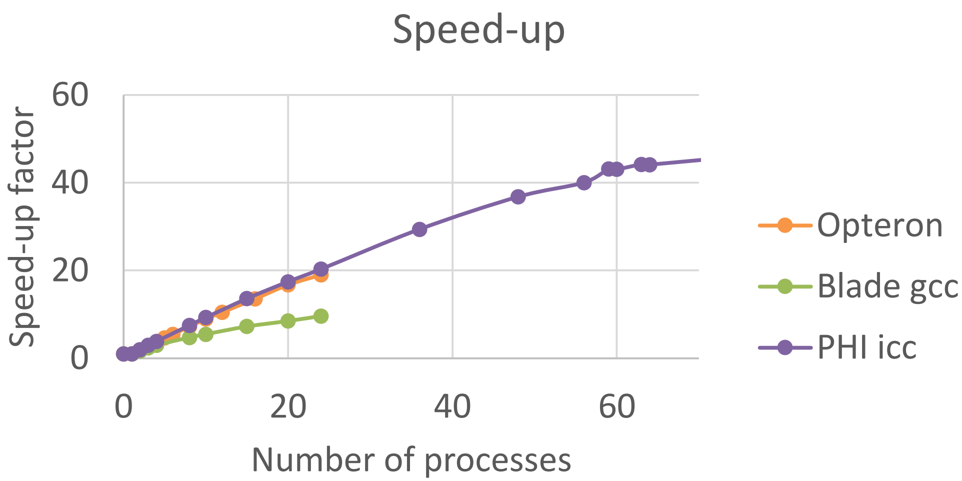


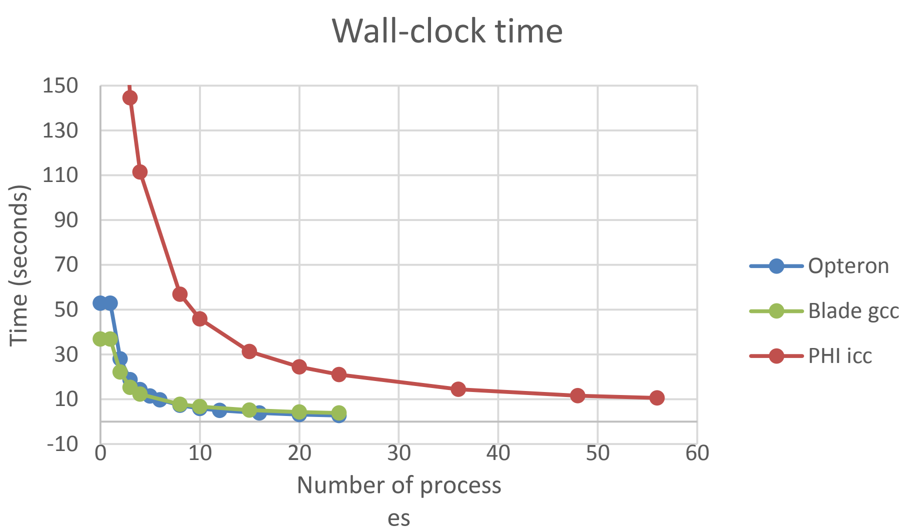
Wall-clock times per MLEM iteration

Siemens mMR data (span 11)

	Opteron	PHI
NO THREADING	315s	4200s
20 THREADS	20s	~350s

Open-MP for scatter estimation





STIR

Siemens mMR PET support

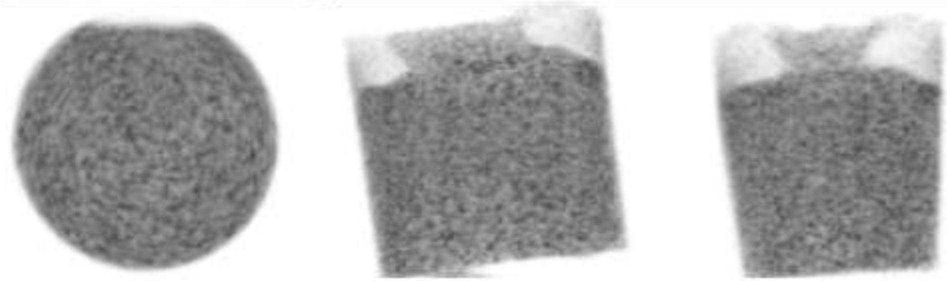
- List mode data
  - 32-bit format only
- Projection data
  - Need decompression using Siemens utility
  - Need to convert “Siemens” Interfile header to “STIR” Interfile header
- Normalisation file
  - efficiencies, geometric, crystal-interference, axial
  - axial factors only for span=11
  - no dead-time yet
- Randoms
  - Delayeds
  - Randoms from ML singles
- Currently missing
  - no exact alignment between MRAC and PET
  - Bed AC map

STIR

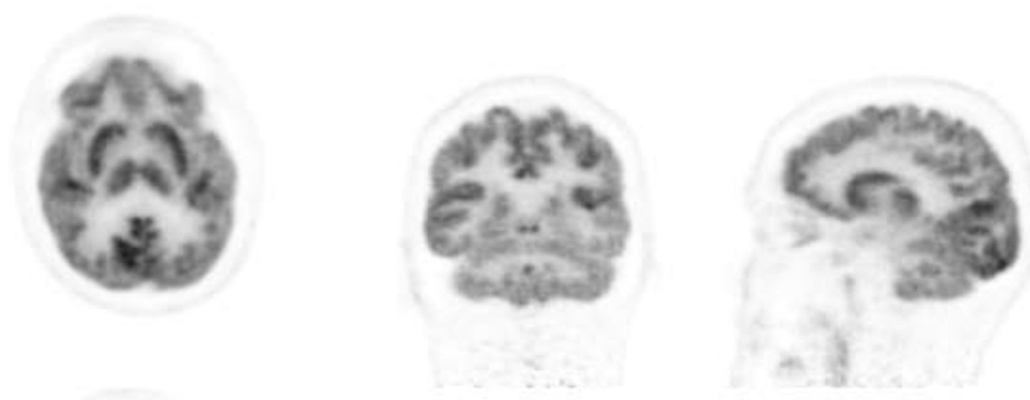
Example results

μ-map

Reconstructed image with the 3 iterations and 21 subsets, smoothing with a Gaussian of 2mm (FWHM)



FDG human brain image reconstruction



Estimation of accidental coincidences

- Delayeds

- Randoms From Singles (RFS)

$$R_{ij} = 2\tau S_i S_j$$

Randoms rate

Singles rates

Provide nearly noiseless estimate of the mean background.

STIR

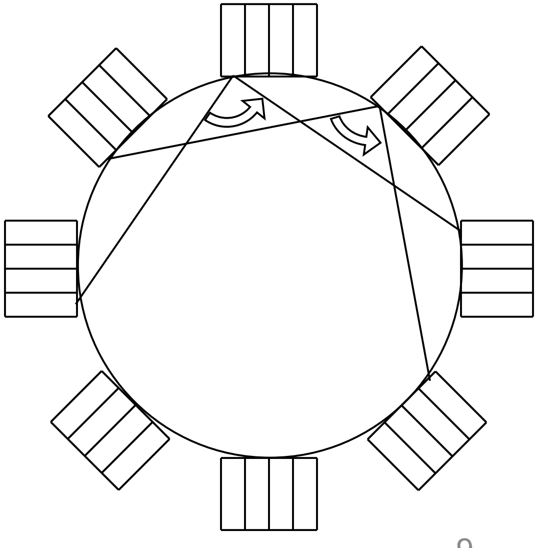
Component-based normalisation

$$\varepsilon_{ij} = \varepsilon_i \varepsilon_j B_{ij} g_{ij}$$

Crystal efficiency (ε_i, ε_j)
Block-timing (B_{ij})
Geometric effects (g_{ij})

Impose symmetries to reduce number of independent components.

Example: symmetries on g_{ij}



How to find these factors?

– **Current practice**:
  Find various components based on specific measurements with known sources (ignoring interdependencies).

– **State-of-the-art:**
  Use Maximum Likelihood estimation in an iterative process.

STIR

Iterative Coordinate Ascent ML

Find scale: $\varepsilon_j^{(0)} = \alpha$

$$\alpha^2 = \sum_{ij} y_{ij} \Big/ \sum_{ij} A_{ij}$$

Initialise with fan-sums:

$$\varepsilon_k^{(1)} = \sum_{i \in F_k} y_{ik} \Big/ \sum_{i \in F_k} \alpha\, A_{ik}$$

Iterate:

$$\varepsilon_k^{new} = \sum_{i \in F_k} y_{ik} \Big/ \sum_{i \in F_k} \varepsilon_i\, A_{ik}$$

1. D. Hogg, **K. Thielemans**, T. Spinks, N. Spyrou, *Maximum-Likelihood Estimation of Normalisation Factors for PET*, proc. of IEEE Medical Imaging Conf. 2001, vol. 4 pp. 2065 - 2069.
2. M. W. Jacobson, **K. Thielemans**, *"Optimizability of LogLikelihoods for the Estimation of Detector Efficiencies and Singles Rates in PET"*, Conf. Rec. IEEE NSS-MIC 2008, Dresden, Germany.

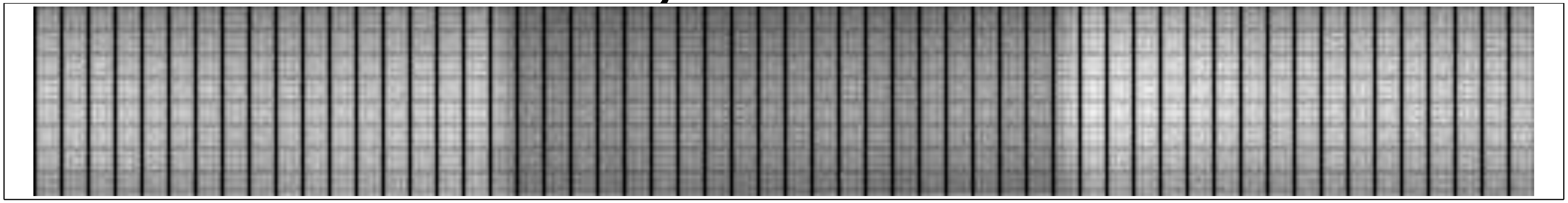
Algorithm can be shown to converge to ML solution if it exists

(Jacobson M. and Thielemans K., to be submitted)

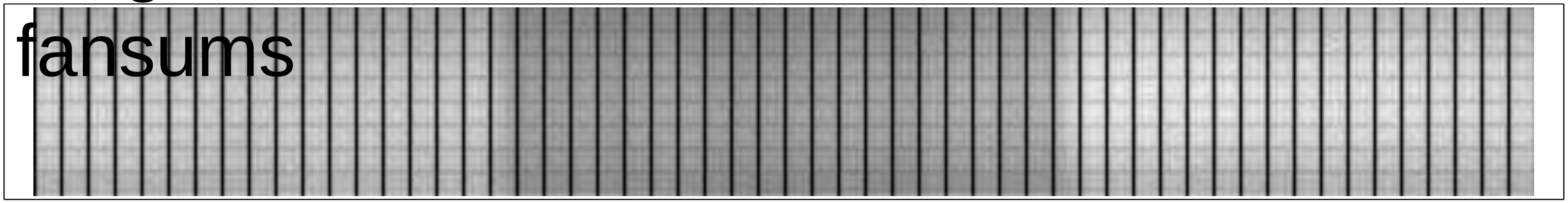
Singles estimation using ML

$$R_{ij} = 2\tau S_i S_j$$

Fansums from delayeds

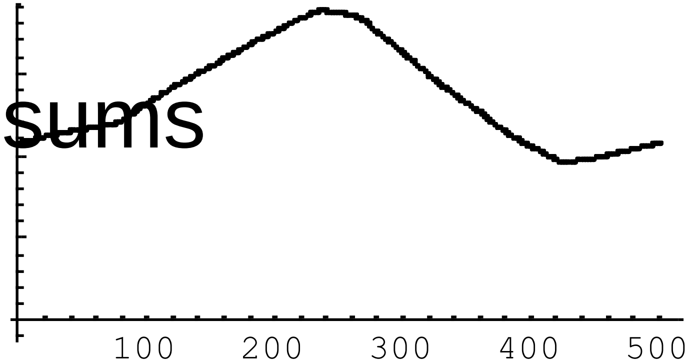


Singles estimated from fansums



Ratio of fan-sums and singles

("round" the ring)

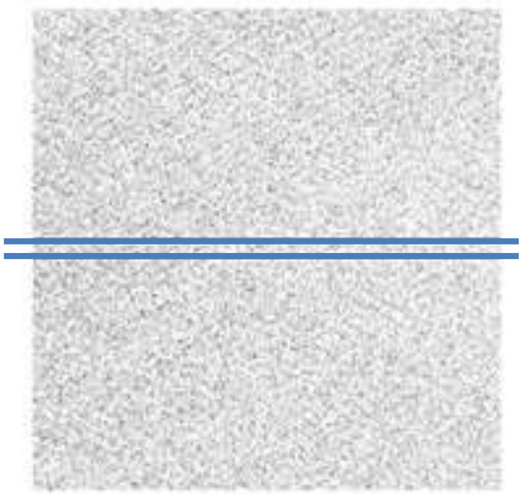


Cylinder data measured on Siemens mMR

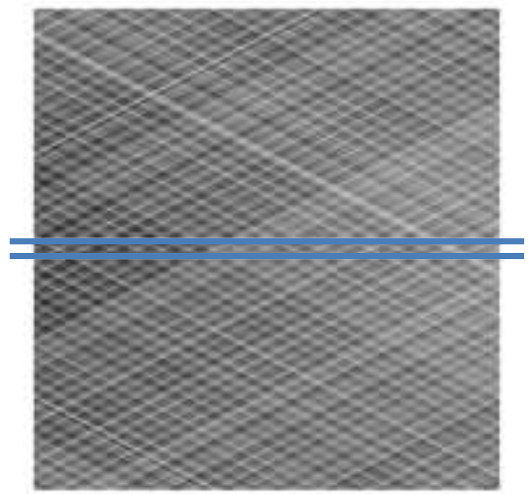
STIR

Randoms estimation using ML

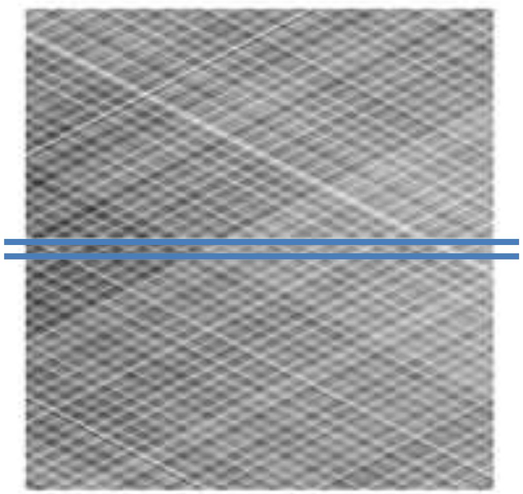
Delayeds, 300s

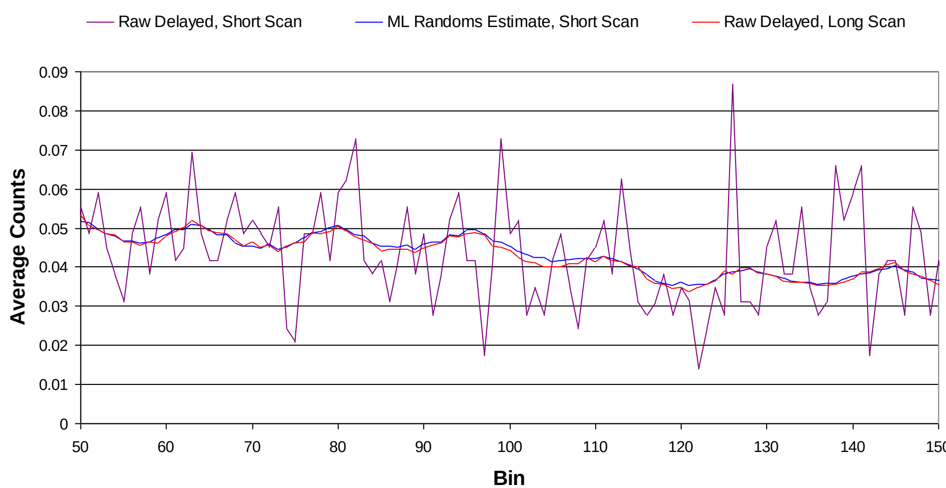


ML randoms estimate, 300s



Delayeds, 200000s





Cylinder data measured on CTI EXACT 3D

Caveats on ML normalisation code

- Undocumented
- Geometric code is currently 2D only
- Block timing model has too much freedom (best to switch this off)

STIR

Other developments

- STIR on github
  https://github.com/UCL/STIR

- Virtual Machine with STIR pre-installed
  Lubuntu, STIR+Python

STIR

Future contributions

- 4D Generalised Patlak for multi-bed position data
  Nicolas Karakatsanis

- List-mode reconstruction fixes
  Nikos Efthimiou & Charalampos Tsoumpas

- TOF
  Nikos Efthimiou & Charalampos Tsoumpas

- Support for GE PET-MR

STIR

EPSRC

Engineering and Physical Sciences Research Council

Synergistic PET-MR Reconstruction

STIR

CCP in Synergistic PET-MR Reconstruction

- **5 year** funding (April 2015 – March 2020)

- Budget for networking activities

  £140K (RC contribution)
- Budget for management (PI, CoIs)

  £110K (RC contribution)
- Core support
  - Scientific programmers: **1 FTE** (for 5 years)
  - Administration: **0.25 FTE** (for 5 years)

STIR

Aims

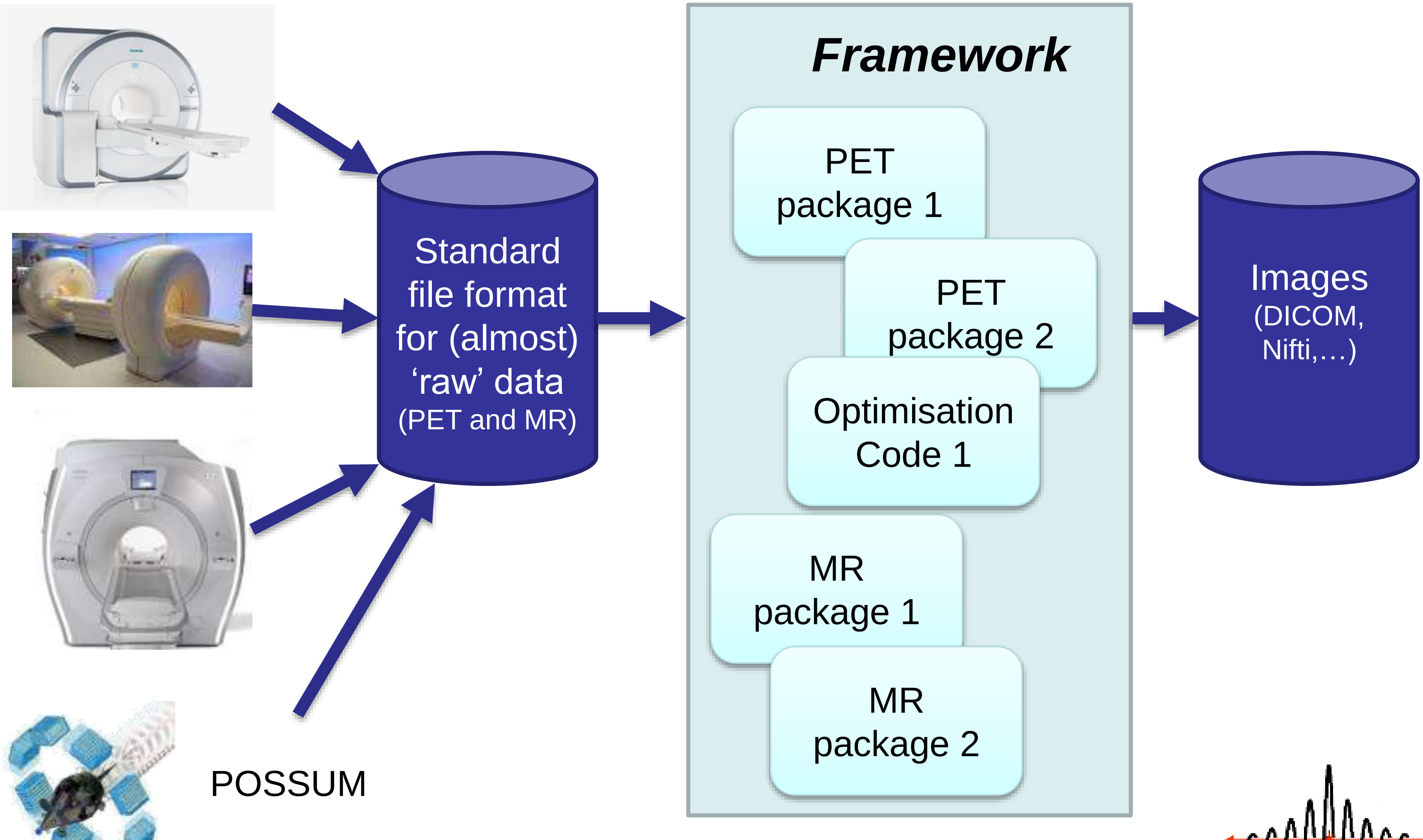
- Network formation: bringing together expertise in each modality
  - advancing understanding of PET-MR
  - enhancing understanding of the algorithms used for each modality
- Developing software infrastructure
  - creating an Open Source software platform for integrated PET-MR image reconstruction
  - standardisation of data formats
  - database with test cases

Software

- ***Framework*** for 3D and 4D reconstruction of PET-MR data
- ***Simple enough*** for education and teaching
- ***Powerful enough*** for processing of real data in a research context
- ***Open Source***
- ***Easy installation***
  (e.g. installation script, precompiled, virtual machine, Docker)

STIR

Architecture overview



File format translators supplied by/developed with manufacturers

Main publication:

Thielemans, Tsoumpas, *et al* (2012) STIR: Software for Tomographic Image Reconstruction Release 2, *Physics in Medicine and Biology*, 57(4):867-83.

Thanks:

- GE Research
- CCP PET-MR
- IEEE