ASIM-STIR

IMAGING RESEARCH LABORATORY
UNIVERSITY of WASHINGTON
Department of Radiology

ASIM-STIR PET images.

Brian Elston : belston@uw.edu : Nov-1-2012

Example PET images simulated with ASIM, reconstructed with STIR OSEM.
UW-IRL Nuclear Medicine 2012 : IEEE NSS-MIC Anaheim, CA. USA

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ASIM
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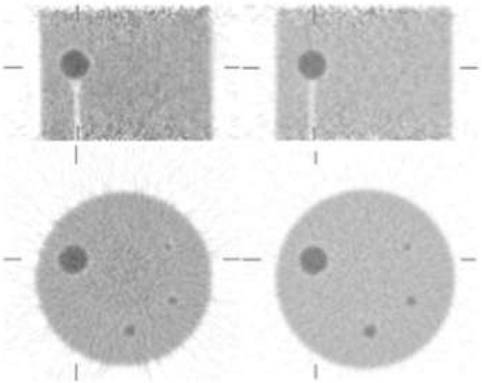
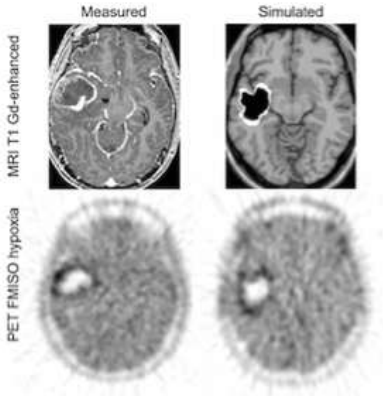
Home of the ASIM PET simulation software package.
Revised: October 15, 2012

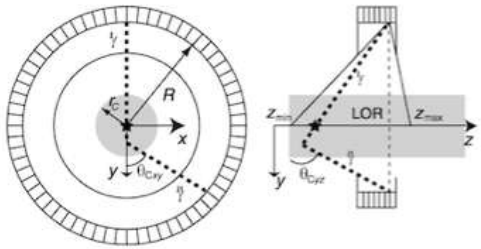
ASIM is a software package designed as a fast analytic simulator for positron emission scanners. This process uses a monte-carlo approach to allow the rapid generation of multiple realizations with realistic resolution properties. The simulator provides a wide variety of options including the simulation of emission data, image data, randoms, scatter, detector efficiencies, attenuation correction, normalization, and noise propagation.



Transverse orthogonal sections through a 20 cm diameter cylindrical phantom with hot spheres supported by plastic rods. Left: Measured data from a Siemens/CTI ECAT HR+ scanner. Right: Simulated data for the same acquisition using ASIM.



Measured and simulated images of MRI and PET images of hypoxic glioma tumor cells. (From Gu S et al. Math. Med. Biol. 2011.)



The geometry of the calculation of scatter for acquisitions without septa. Because of the Compton scattering, both single photons and the scanner axis can not be considered as lying in the same plane.

ASIM/Simset users and collaborators:
ASIM/Simset Users group.

ASIM: An Analytic PET Simulator

The ASIM package is 3 applications

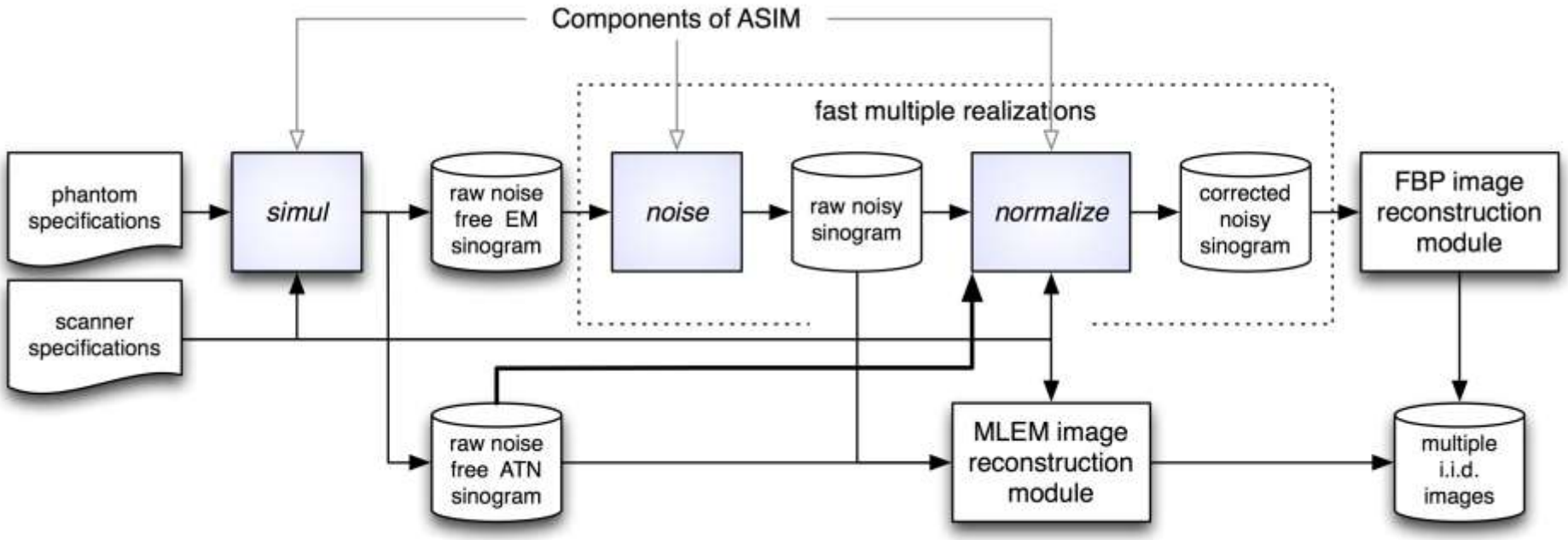
1) **Simul**: Generates noiseless PET emission and attenuation sinograms
2) **Noise**: Applies Poisson-distributed noise to a sinogram
3) **Normalize**: Applies corrections to these data sets

This sinogram data then can be reconstructed with a variety of tools, including STIR

Core Concepts

- ASIM provides a fast simulator for positron emission scanners
- All effects are calculated rather than arising from photon-tracking
- Ability to quickly produce multiple noisy realizations
- Allows for Poisson-distributed noise and corrections to be applied in a sequence representative of clinical practice
- Includes effects such as attenuation, arc correction, psf, axial normalization, and others
- Difficult to properly model contaminants such as scatter and randoms

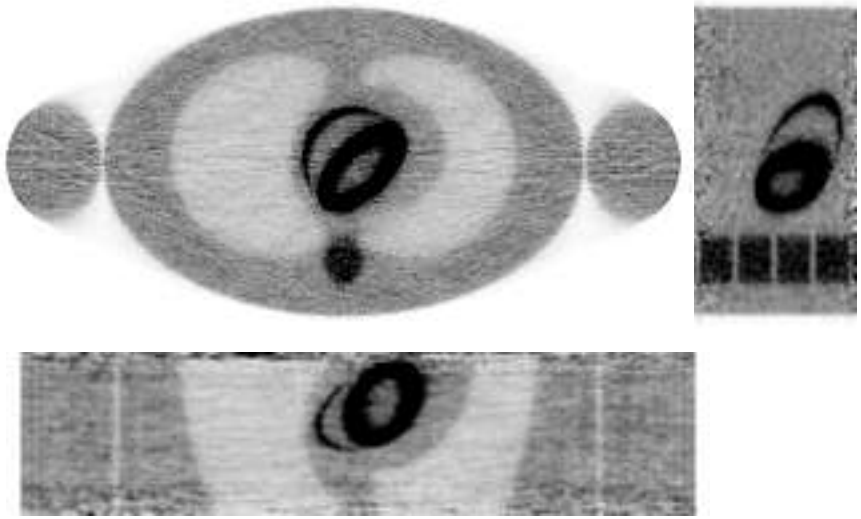
ASIM: Process



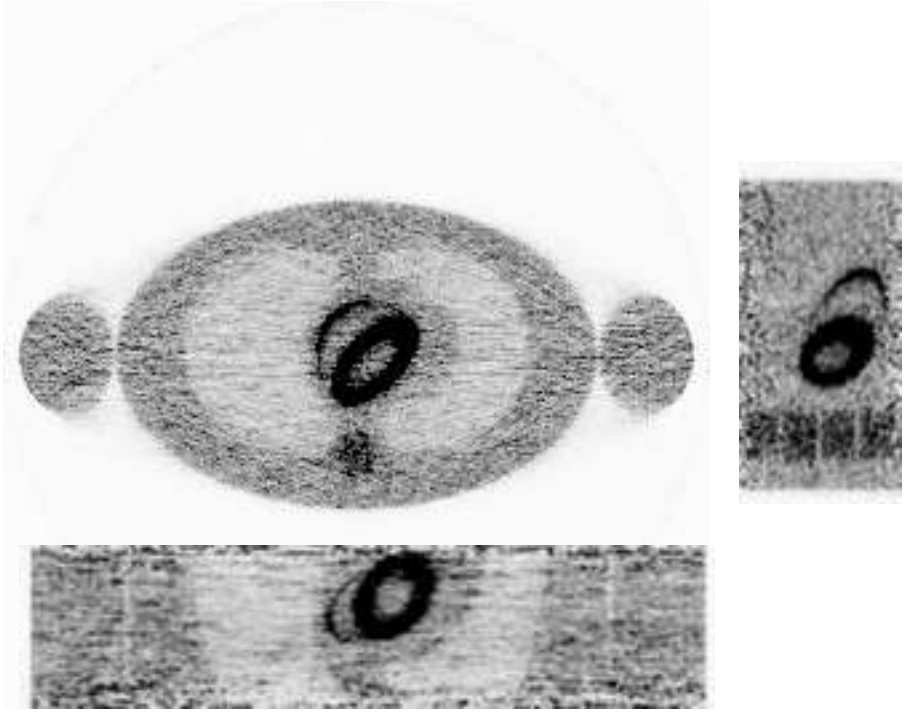
Typical procedural flow using Simul, Noise, and Normalize to generate multiple realizations for an example study. Here one (or potentially more) raw noise-free EM (emission) sinograms are created along with a raw noise-free ATN (attenuation) sinogram.

Image reconstruction is performed with filtered-backprojection (FBP) or Maximum-Likelihood Expectation-Maximization (MLEM) to obtain multiple independent identically distributed (i.i.d.) images.

Arsene: noisy emission : OSEM



756 million trues
26.46 million scatter
756 million randoms -q
C = 0.48



100 million trues
3.5 million scatter
100 million randoms -q
C = 3.64

12 subsets/ 2 iterations

Scatter and random corrected (-q: unbias and noiseless correction)

Simul -i arsene.data -o arsene_ESD.yaff -E -m 962 -h -k –S –D -f 365 –d 3
Simul -i arsene.data -o arsene_A.yaff -A -m 962 -h -k -f 365 –d 3
Simul -i arsene.data -o arsene_N.yaff -N -m 962 -h -k -f 365 –d 3
Noise -i arsene_ESD.yaff -t 756000000 -r 756000000 –q -s 26460000 -o arsene_E_Ns_tsSrqR.yaff
Normalize -i arsene_E_Ns_tsrq.yaff -o arsene_ankSR.yaff -k –S –R -a arsene_A.yaff -n arsene_N.yaff

STIR OSEM Reconstruction

Summary of recent ASIM work

- Re-architecture of code base; improved modularity, documentation, and ease of use
- Addition of LORSAS (Line Of Response Solid Angle Scaling);
  allows ASIM arc effect to be compatible with STIR
- Implementation of a new I/O format that separates header (.yhdr) and sinogram data (.yaff)
- Implementation of ASCII headers and external ASCII scanner model definition files
- Ability for Noise to composite two input sinograms, along with a multiplicative factor (for tumor variability studies)
- Documentation and user tutorials
- Open source code release including website

Converting ASIM output to STIR .hs input

ASIM Simul –E screen display example:

Maximum rings difference is 22
Span factor is 9
Number of segments is 5
Segment 0 is for ring difference -4 to 4
and goes from slice 0 to slice 62
Segment 1 is for ring difference 5 to 13
and goes from slice 5 to slice 57
Segment -1 is for ring difference -13 to -5
and goes from slice 5 to slice 57
Segment 2 is for ring difference 14 to 22
and goes from slice 14 to slice 48
Segment -2 is for ring difference -22 to -14
and goes from slice 14 to slice 48
Number of radial pixels is 288
Number of views is 144

ASIM Normalize screen display example:

Number of slices per occurance of segment is 63, 53, 53, 35, 35

STIR .hs header file example:

```
!type of data := PET
imagedata byte order := BIGENDIAN
!number format := float
!number of bytes per pixel := 4
number of dimensions := 4
matrix axis label [4] := segment
!matrix size [4] := 5
matrix axis label [3] := view
!matrix size [3] := 144
matrix axis label [2] := axial coordinate
!matrix size [2] := { 63,53,53,35,35}
matrix axis label [1] := tangential coordinate
!matrix size [1] := 288
minimum ring difference per segment := { -4,-13,5,-22,14}
maximum ring difference per segment := { 4,-5,13,-14,22}
```

Current conversion process

Conversion of ASIM Simul output statistics to STIR .hs input

- 1) Set to ’BIGENDIAN’, ’float’, and ’4’ bytes per pixel for Simul emission output
- 2) Simul ’radial pixels’ is STIR ’tangential coordinate’
- 3) Simul ’views’ is STIR ’view’
- 4) Simul ’Number of segments’ is STIR ’segment’
- 5) Reorder Simul ’Segment’ output to match STIR ring differences
  a) minimum ring difference per segment
  b) maximum ring difference per segment
- Note: ASIM segments ordered {0, 1, -1, 2, -2} while STIR ordered {0, -1, 1, -2, 2}
- Note: STIR min/max directly correspond to the Simul output for the appropriate segment
- 6) Simul ’and goes from slice #n1 to #n2’ is STIR ’axial coordinate’ as (n2-n1)+1
  -create a list corresponding to the length of the scanners segments for STIR
  -alternatively use slices per segment output from NORMALIZE

I’d like to thanks the funding agency’s and numerous contributors to the work presented here.

The End.

Thank You.

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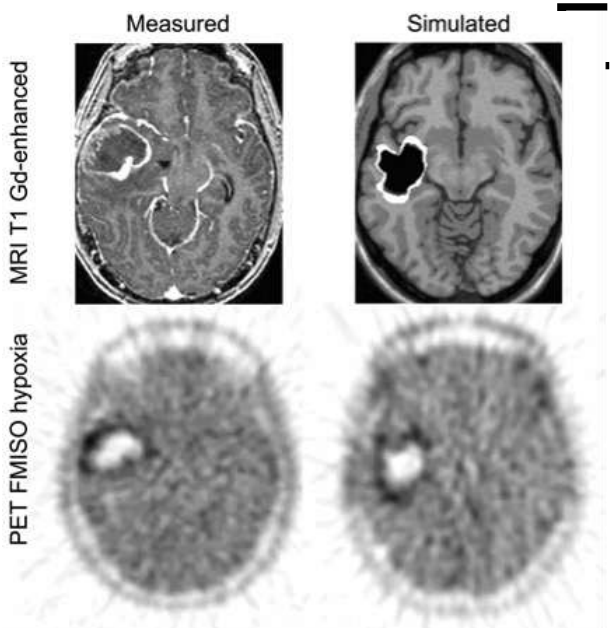
Contact: belston@uw.edu

ASIM Extras



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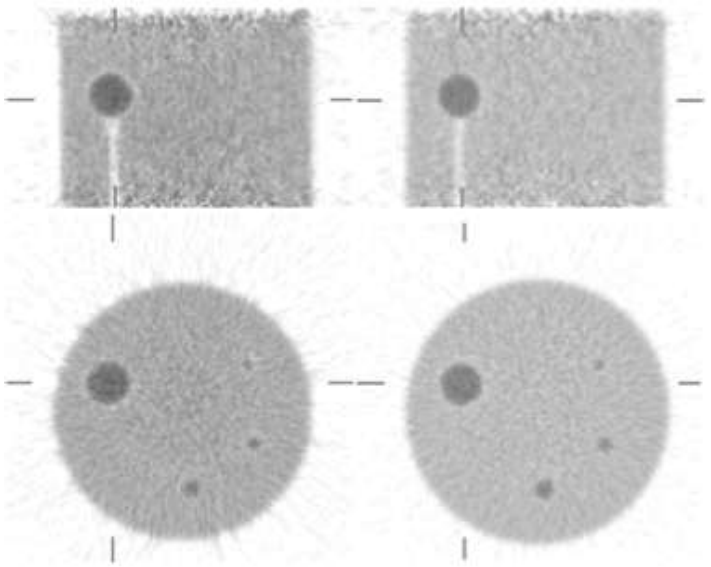

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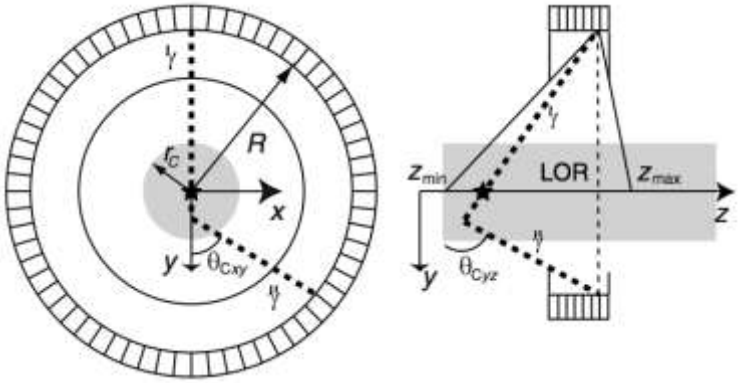

The geometry of the calculation of scatter for acquisitions without septa. Because of the Compton scattering, both single photons and the scanner axis can not be considered as lying in the same plane.

References

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Special thanks to Adam Alessio, Steven Gillispie, Claude Comtat, Robert Harrison, Paul Kinahan, Tom Lewellen, and the members of the UWMC Radiology department.

Additional contributions provided by

R. Harrison, C. Comtat, K. Thielemans, & P. Kinahan

The Real End.

Really.

Thank You.

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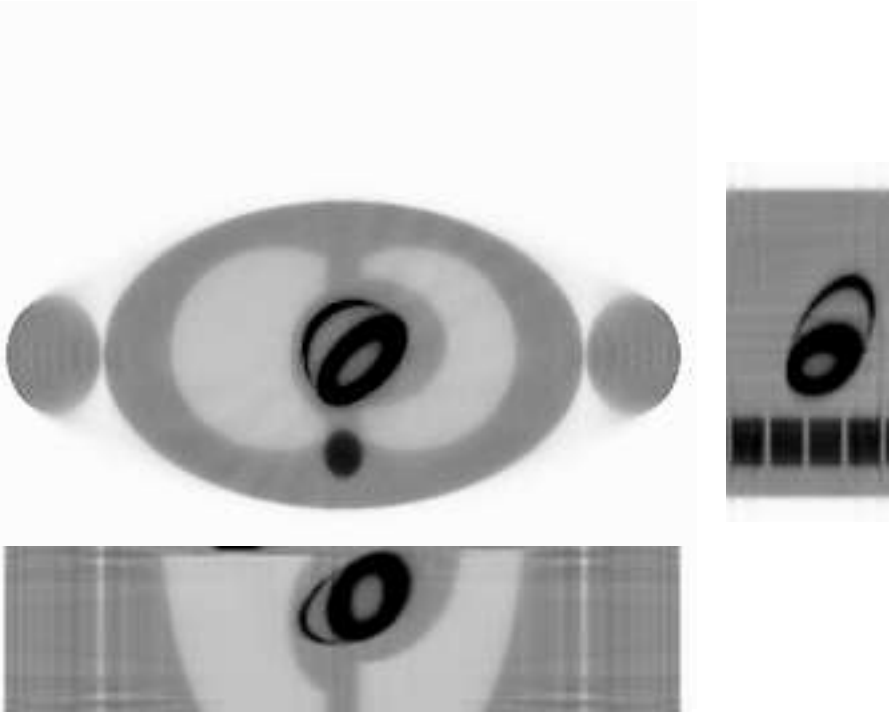
Arsene: noise-free emission : OSEM 3D



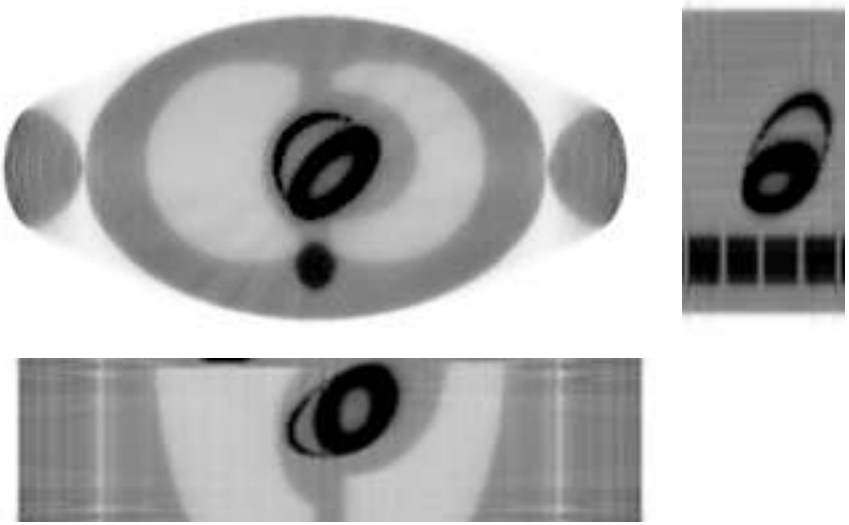
12 subsets/ 2 iterations

Location: chest in cardiac region.
Attenuation corrected, axially normalized, & arc corrected

Simul -i arsene.data -o arsene_E.yaff -E -m 962 -h -k -f 365 –d 3
Simul -i arsene.data -o arsene_A.yaff -A -m 962 -h -k -f 365 –d 3
Simul -i arsene.data -o arsene_N.yaff -N -m 962 -h -k -f 365 –d 3
Normalize -i arsene_E.yaff -o arsene_E_ank.yaff -k -a arsene_A.yaff -n arsene_N.yaff

minimum ring difference per segment := { -4,-13,5,-22,14}
maximum ring difference per segment := { 4,-5,13,-14,22}
STIR OSEM Reconstruction

Arsene: noise-free voxelized input: OSEM 3D



12 subsets/ 2 iterations

Attenuation corrected, axially normalized, & arc corrected
Image simulated with ASIM (-I); 256x256; Then used as input for emission simulations

Simul -i arsene.data -o arsene_I.yaff -I -m 962 -f 365 -e 256
Simul -i arsene_I.yaff -o arsene_I_E.yaff -E -a -m 962 -h -k -d 3
Simul -i arsene_I.yaff -o arsene_I_N.yaff -N -m 962 -h -k -d 3
Normalize -i arsene_I_E.yaff -o arsene_I_E_ank.yaff -k -n arsene_I_N.yaff

STIR OSEM Reconstruction