Initial Validation of Time-Of-Flight List-Mode MLEM and OSEM Reconstruction Algorithms in STIR framework, using Monte Carlo simulated data

Nikos Efthimiou[1,2,3], Kris Thielemans[3] and Charalampos Tsoumpas[1]

1.Division of Biomedical Imaging, University of Leeds
2. Biomedical Engineering, Technological Educational Inst. of Athens
3. Inst. of Nuclear Medicine, University College of London

Objectives

1. Demonstrate the performance of the newly implemented Time-Of-Flight feature in STIR reconstruction framework
2. Present improved image quality on reconstructed images with TOF reconstruction over non-TOF.

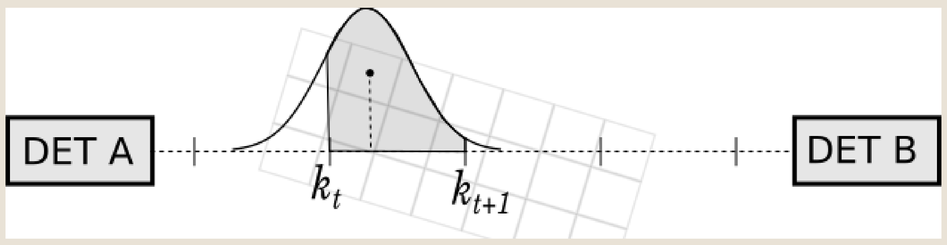
Introduction

Recent advances in PET instrumentation have sparkled up the interest for time-of-flight (TOF) reconstruction. In TOF the difference between the two γ photons detection time provides additional localisation information, in the annihilation point.

Materials and Methods

In order to test and validate our code we used Monte Carlo simulated data. A NEMA phantom with activity ratio ≈4:1 with the scanner geometry of Siemens mCT, were used. The timing resolution of the scanner was set to 600ps. Two datasets of $\mathbf{5 \times 10^6}$ and $\mathbf{20 \times 10^6}$ true events were created. Random and scattered coincidences, normalisation and attenuation effects, were not considered in this investigation.

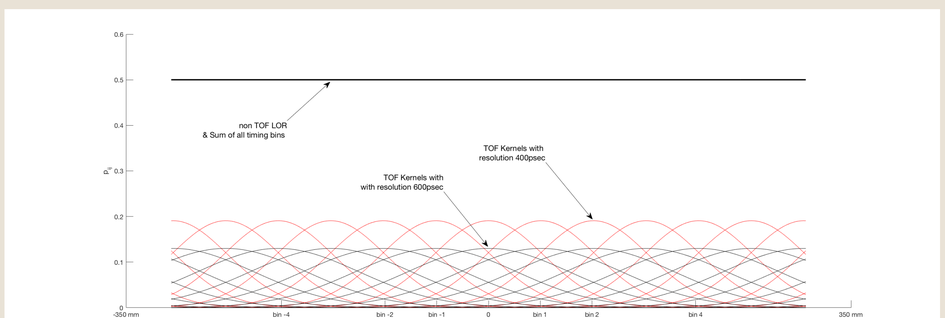
Implementation



The coincidence window of 4.1ns was divided in 311 equally spaced timing bins of 13.3ps, which represented the duration of the least significant bit of the scanner's clock. These timing bins were mashed to 24 TOF bins ($\mathbf{k}$), using a mashing factor 13. The central point of each voxel($\mathbf{j}$), in the nonTOF LOR ($\mathbf{i}$) was projected on the line connecting the centers of the two detectors ($\mathbf{proj_{vj}}$). This tof kernel was centered to this point and integrated for $\mathbf{[t_k, t_{k+1}]}$. The tof probability ($\mathbf{p_{ijk}}$) was calculated by the following formula, where σ is the standard deviation of the timing resolution:

$$\mathbf{p_{ijk}} = \left(\mathbf{erf}\left(\frac{\mathbf{k_{t+1}} - \mathbf{proj_{vj}}}{\sigma\sqrt{2}}\right) - \mathbf{erf}\left(\frac{\mathbf{k_t} - \mathbf{proj_{vj}}}{\sigma\sqrt{2}}\right)\right) \times \mathbf{0.5} \qquad (1)$$

TOF kernels

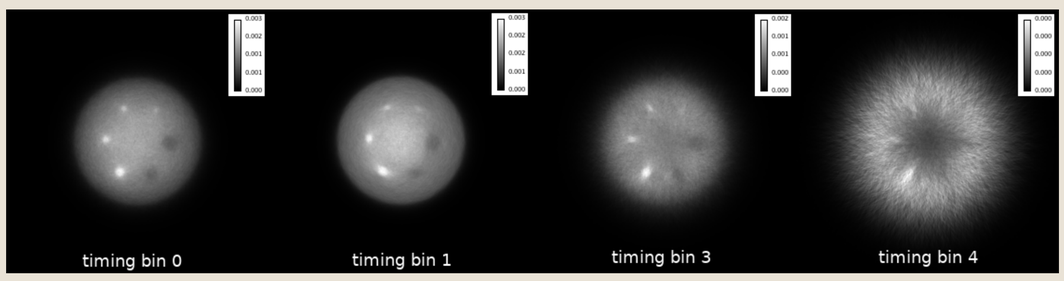


The sum over all TOF bins should be the non-TOF LOR, as demonstrated in the figure above, for two timing resolutions 600 psec and 400 psec.

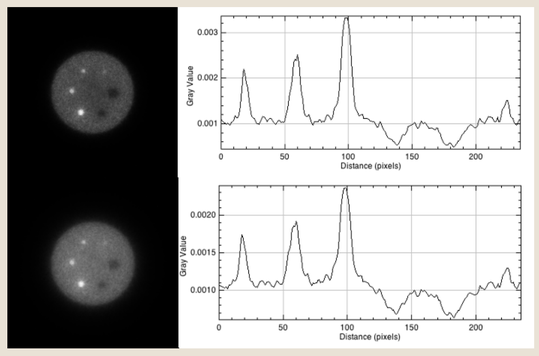
Contact Information

- Email: nikos.efthimiou@gmail.com

Reconstructed images of one timing bin



Results: Reconstruction with MLEM



The Figure on the side present MLEM reconstructed images with and without TOF, after 8 iterations. For the hot source with radius 5mm the CRC is about 0.77 with TOF and 0.4 without. The SNR values are

CRC

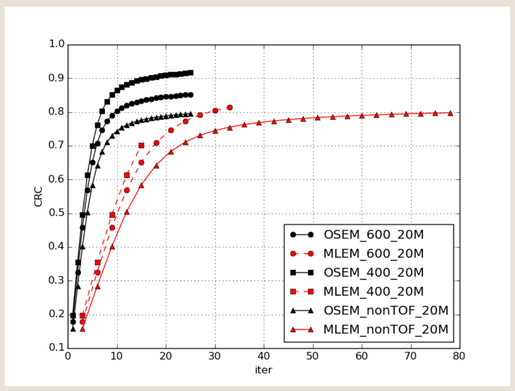
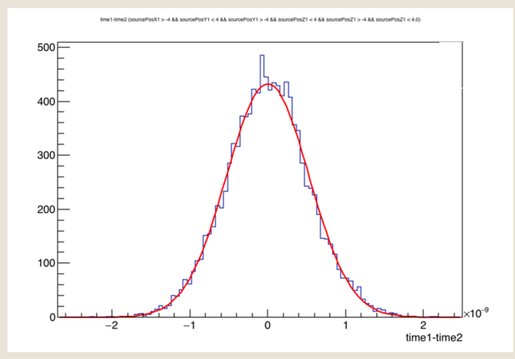


Figure 1: CRC for the hot source with diameter 10 mm for the first 80 iterations

Data and Model mismatch?



DeltaT for events originates from near the center of the FOV. Fitting demonstrates $\sigma = \mathbf{580ps}$

Conclusion

- TOF demonstrates higher CRC values.
- Convergence with lower number of iterations has a positive impact to the SNR values.
- Initial validation results showed that the implementation of the algorithm performs as expected. Further investigation is on going.
- Independent tests to check whether our data match to our model have to be devised.

References

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[3] A. Mehranian et.al, Phys. Med. Biol., vol. 61, 13091331, 2016.

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