Data-driven Improved Sampling in PET

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INTRODUCTION

• Physical effects in the emission and detection of radiation [1] limits the resolution in Positron Emission Tomography (PET).

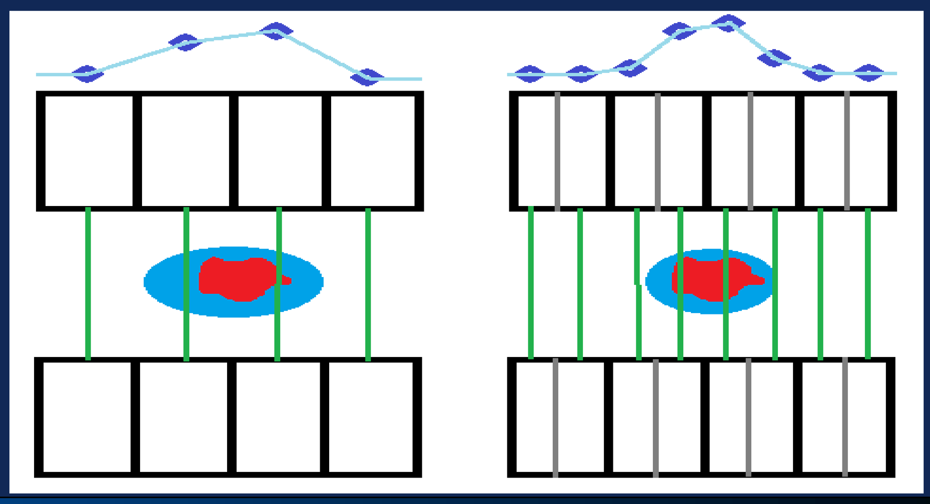
• They can be compensated using a realistic system response matrix [3] with iterative reconstruction methods (OSEM).

• However, resolution recovery is often limited by the reduced sampling in the projection space.

• Reducing the size of the crystals of the PET detectors may increase this sampling, but it compromises other parameters.

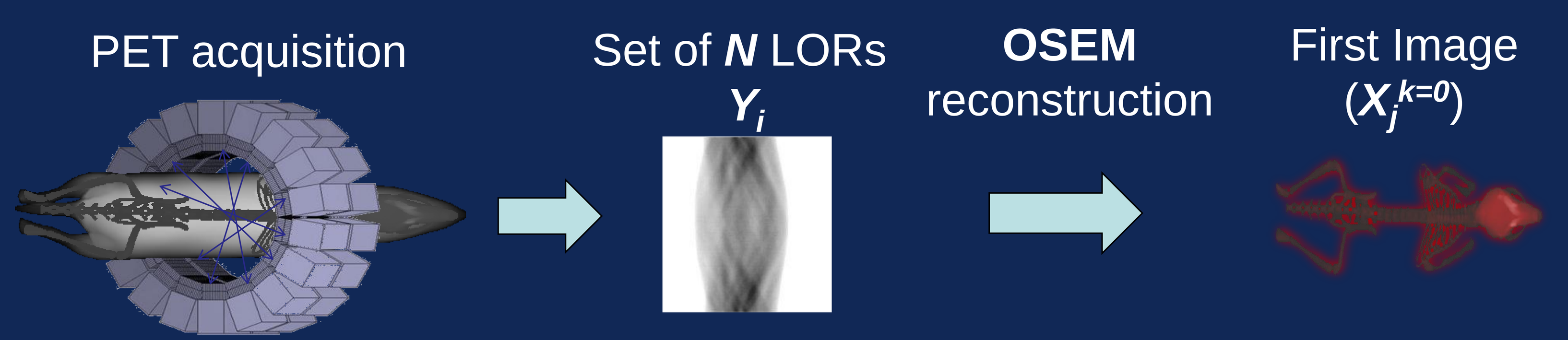
• In this work, we propose an algorithm to improve iteratively the sampling using data-driven virtual crystal subdivisions.

• Its results outperform the resolution obtained with standard methods.



THE SUPERITERATIVE ALGORITHM

Step 1) Standard OSEM Reconstruction



Step 2) Estimation of the Augmented Data Sampling

Each crystal is subdivided into two virtual halves
→ Each LOR Y_i is divided into 4 subLORs $Y_{i,h}$ ***(h=1…4)***

$$Y_{i,h}^{k} = Y_i \cdot W_{i,h}^{k}, \quad W_{i,h}^{k} = P_{i,h}^{k}/P_i^{k}, \quad P_i^{k} = \sum_h P_{i,h}^{k}$$

The weights $W_{i,h}$ are obtained using the relative values of the projection $P_{i,h}$ in each subLOR [4,5] respect to the total projection in the LOR P_i, using the last reconstructed image.

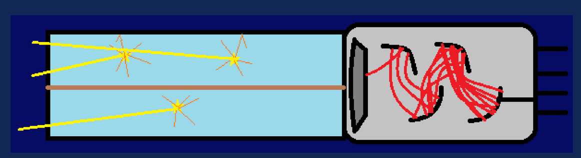
Step 3) Standard OSEM reconstruction of the Augmented Data set.

Repeat steps 2-3 until convergence
We called **each loop k** a **superiteration**
Typically, two or three superiterations are enough

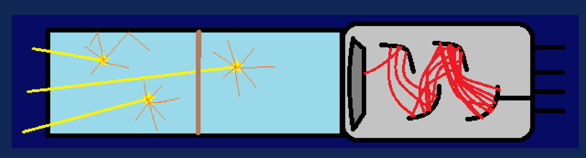
❑ The proposed method simply redistributes the counts acquired within the crystals and therefore it preserves the statistics of the acquisition.

❑ The algorithm does not define how the subdivision of each crystal has to be done. Two different cases have been evaluated:

• Data-driven Resolution Recovery – By sub-dividing the crystal in the transverse direction we can increase the sampling and resolution of the image in the XY-plane.



• Data-driven DOI correction – By sub-dividing the crystal in the longitudinal direction we can create a virtual Front and Back detector similar to one with phoswich [2].



DISCUSSION AND CONCLUSIONS

• Our Data-driven Improved Data Sampling method is able to achieve significantly better resolution-noise curves (Fig.1).

• A peak-to-valley ratio increase of ~50% respect to standard methods has been achieved (Fig.2). This is a significant improvement for a software-based correction.

• The superiterative method increases several times the reconstruction time, but this is not a significant problem with current high-performance computers and GPUs.

• Further studies on the impact of the method on all the relevant parameters of image quality are ongoing to prove the best performance of the method.

RESULTS

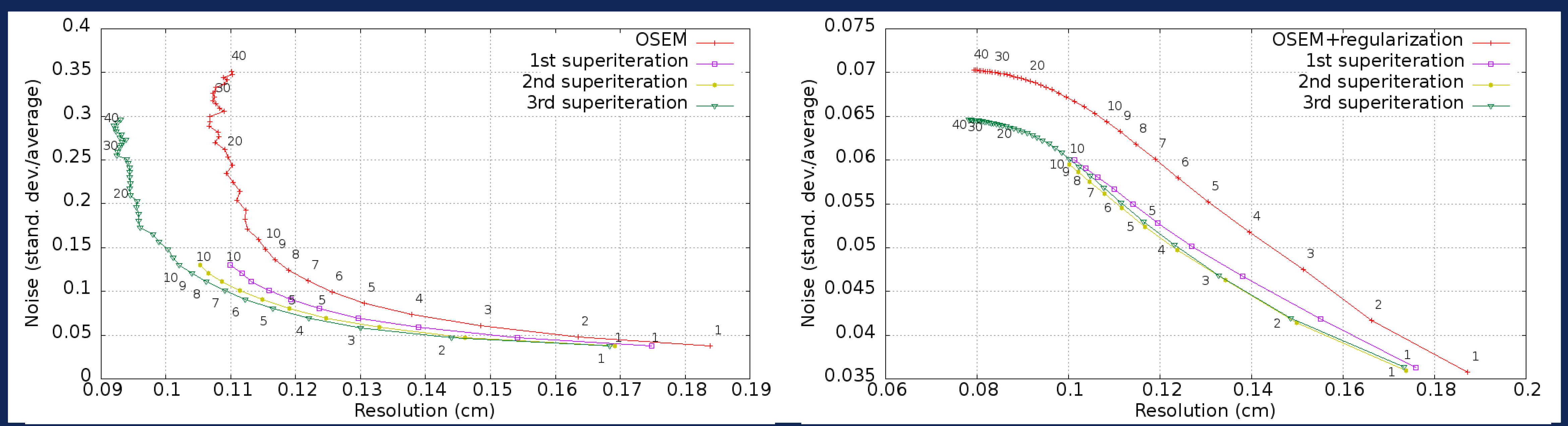


Figure 1. Noise-resolution curves for an IQ phantom filled with ^{18}F-FDG acquired with the preclinical Argus PET/CT scanner [2] reconstructed using standard OSEM (10 subsets) (LEFT) and MAP-OSEM [6] with 10 subsets, β=0.08 (RIGHT). The number of iterations of each point is indicated. It is clear that by using superiterations the resolution-noise is improved

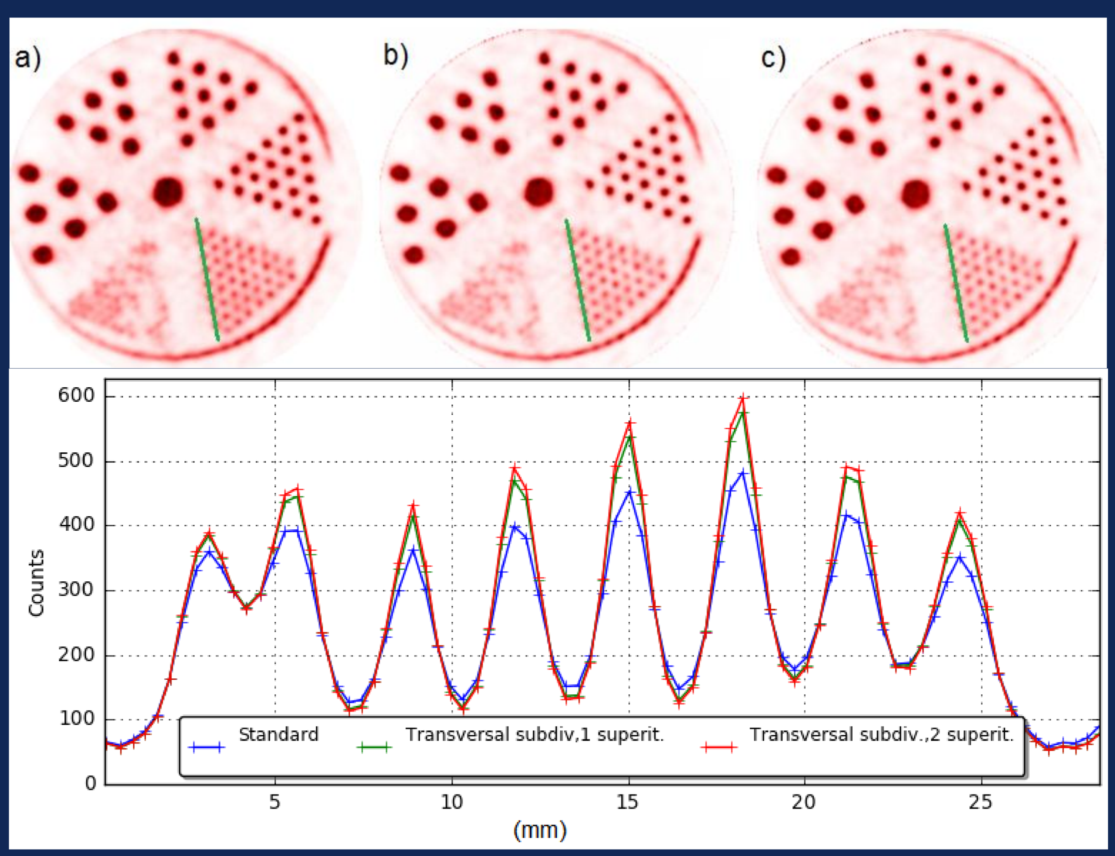


Figure 2. Reconstructed Super-Derenzo Phantom acquired with the Super Argus [2] scanner. (a) Standard reconstruction OSEM (20 iterations, 5 subsets) and after 1 and 2 superiterations recovering transverse information (b and c). The line profile along the green line is shown at the bottom (1.5 mm rods).

# of superiterations	Peak-to-valley increase (%)	Noise increase (%)
1	41±3	10
2	54±3	13

Table 1. Peak-to-valley ratio increase along the profile shown in Fig. 2 and noise increase in the central rod respect to standard OSEM reconstruction.

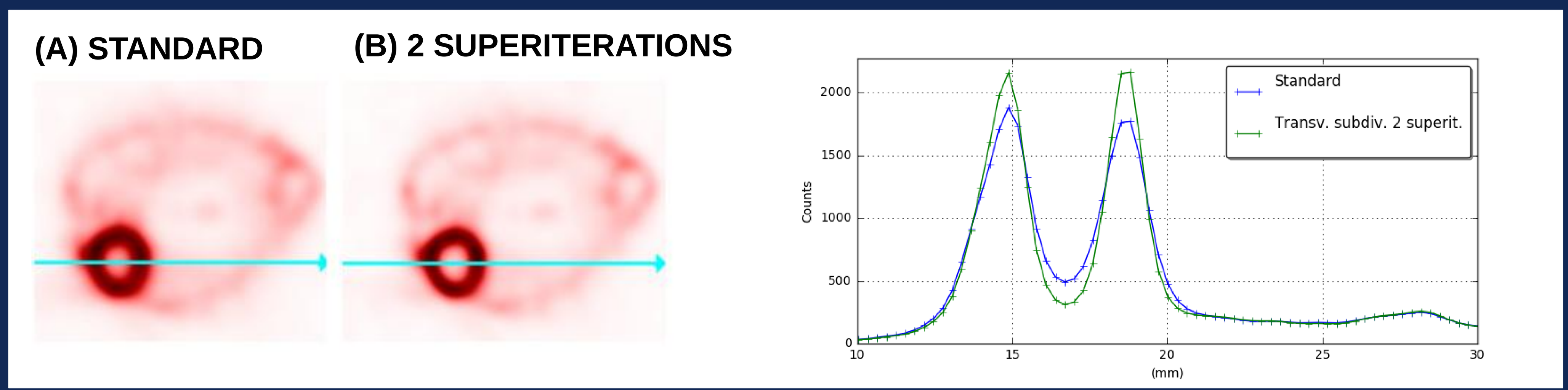


Figure 3. Transverse view of a rat heart injected with FDG and acquired with the Argus [2] scanner. (A) Standard reconstruction OSEM (10 iterations, 10 subsets). (B) After 2 superiterations with same parameters.. The line profile along the blue line, crossing the heart, is shown on the right. A significant improvement in the resolution and reduction of the spill-over of the myocardium activity into the left ventricle is seen.

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