DESIGN OF A HIGH RESOLUTION SMALL ANIMAL OCTAGONAL PET SCANNER: PRELIMINARY STUDIES

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Introduction: We present a preliminary study on the design of a high resolution small animal octagonal positron emission tomography (PET) scanner, based on Monte Carlo simulations. The purpose of this study is to evaluate the impact of several critical design parameters on the reconstructed image quality, as well as the calculation of the system matrix for iterative image reconstruction based on statistical models.

Materials and Methods: The basic tomograph design consists on eight planar detector blocks in octagonal configuration. The number and size of the individual crystals, as well as the exact position of each block and the size of the angular gaps between them are some of the variables of the design optimization procedure. For the depth of interaction effect simulation LSO scintillator characteristics have been used, but inter crystal gamma or light scatter is not enabled. Activity distributions are generated based on several classes of parametric volumes placed in the field of view (FOV). Coincidence data are stored in histogram mode without rebinning, and coincidences are allowed among one detector and the three or five opposites, resulting in a total of 12 or 20, respectively, possible detector block pairs.

When sinogram-based reconstruction methods are used, coincidence data can be stored in sinograms similar to the ones proposed by Defrise, et al. In octagonal configurations without rotation, each sinogram is composed of characteristic diamond-shaped sections, corresponding to each detector block pair and separated by strips whose width size is related to the angular gap between detector blocks. Non-uniformity artifacts due to sinogram discretization is corrected by normalization. FBP and iterative image reconstruction algorithms based on the maximum-likelihood expectation-maximization (MLEM) and Bayesian approaches are employed, and the system matrix is calculated using the same Monte Carlo approach. Sparse matrix techniques are implemented in order to efficiently represent this matrix structure and achieve fast image reconstruction.

Results and Discussion: The figure shows the results obtained with a simulated phantom. In the direct sinogram, the stripes produced by the angular gaps in the detector geometry are evident. If these gaps are not corrected, they produce large artifacts in the filtered back projection reconstructed image. Iterative reconstructions with the appropriate system
matrix however can deal with the lack of information in these regions, producing correctly reconstructed images.

Conclusions: An octagonal tomograph configuration represents a good compromise between design simplicity, low cost and good sensitivity in comparison to small animal PET scanners employing two rotating detector blocks. The FOV diameter can be increased by separating the detector blocks. In this case, iterative image reconstruction algorithms can produce images which are not affected by the presence of gaps, in contrast to the FBP-based reconstruction methods.

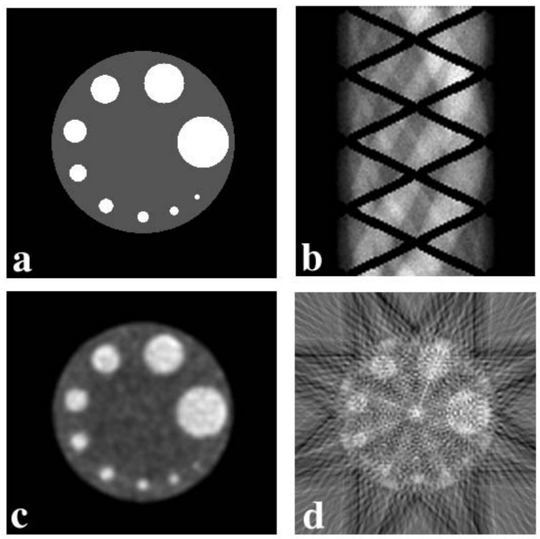

Figure1. *(a) Simulated phantom, Axial view. (b) Direct sinogram from the Defrise set. Note the characteristic stripes generated by the angular gap in between detector blocks. (c) MLEM reconstruction using the system calculated from the simulations. (d) FBP reconstruction from rebinned sinogram without any gap removal technique; window level has been stressed in order to enhance the artifacts due to the sonogram strips.*