# Enhancement of 3D OSEM for Gate simulated XCAT PET image using inter-update median filtering

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## 1. Introduction

Molecular imaging has advantage to refine tumor targeting for radiation therapy planning by biologically based tumor definition. It provides a driving force to integrate the positron emission tomography (PET) image with definition of target volume. The inherent uncertainties in target volume of PET must be understood and controlled. The accurate definition of tumor is necessary for diagnosis and treatment planning. Geant4 application for tomographic emission (GATE) is well suited for implementing realistic phantoms. GATE is useful tool in stage of difficult to calculate by experimental or analytical approach. Recently, it is extensively applied to PET. Ordered subset expectation maximization (OSEM) for PET image has been used usually. Some type of smoothing parameters is required due to the developed noise artefacts produced by increasing iteration. In this study, we produced XCAT phantom and compared PET images in accordance with change of filters.

## 2. Material and Method

### *2.1 XCAT*

The 4D extended cardiac-torso (XCAT) has the advantage of accurate representation of the complex human anatomy and its organs shape [1]. The XCAT can realize internal movement to use mathematical description and voxelized phantom of any desired resolution [2]. Respiratory motion of phantom was implemented by the degree of thoracic expansion and change in the diaphragm height with passage of time. 5 sec of respiration cycle of human was divided into 8 frames as a result the time for each frame was 0.625 sec.

Tumor located in the lung region was produced as a sphere of 2 cm diameter. Activity of phantom was set based on 18F-FDG PET image and activity of tumor, tissue, lung and liver was 2.0 μCi/voxel, 0.2 μCi/voxel, 0.1 μCi/voxel and 0.3 μCi/voxel, respectively. Phantom including lung tumor was produced by fusion of thoracic phantom and tumor image.

### *2.2 GATE Simulation*

Detector can be portrayed with basic geometrical shapes. ECAT EXCAT HR+ PET of GATE 6.0 code was used for simulation. It consists of 4 block rings of 72 detector BGO crystal array block. Size of each crystal are 4.05 mm × 4.39 mm × 30 mm. Diameter of ring is 824 mm while the axial FOV is 155 mm [3]. The geometry of ECAT is described in Fig. 1.

Simulation for voxelized phantom was performed using real-time motion management for voxelized source and phantom (RTVphantom). We used InterFile format to get geometry of phantom and source distribution. Time of each frame was set to 0.625 sec for motion. Simulation was performed during 15 sec and result was acquired by ECAT7 output. At the end of simulation, 3D sinogram was written with an incremental frame indexing.

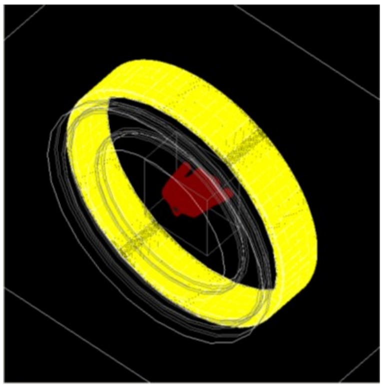

Fig. 1. ECAT EXACT HR+ geometry model using ECAT system in GATE with XCAT phantom

### *2.3 Image Reconstruction and Evaluation*

The rebinning algorithm was used for manipulating the 3D sinogram data set to 2D projection data in PET imaging. The single slice rebinning (SSRB) is the rebinning algorithm and it transfers the data to the axial position in segment 0. The sinogram data was reconstructed using 3D OSEM algorithm with 5 iterations.

The inter-update, inter-iteration and post-filtering can be applied to OSEM algorithm. The inter-update applies filter to the image updating process. In other words, it is applied to the multiplicative image and it is used to update image at certain intervals. The inter-iteration applies filter to the each end of iterations of reconstruction process. The post-filtering applies filter to the end of last iteration. There are median, separable Cartesian Metz and separable convolution for smoothing function.

Uniformity of PET images was calculated using mean and standard deviation of pixel value. Resolution of lung tumor region was measured by full width at half maximum (FWHM) of vertical direction in transverse.

### 3. Result

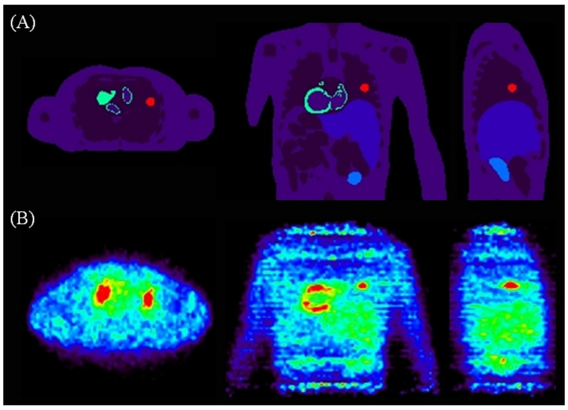


Fig. 2. (A) XCAT phantom image, (B) Reconstructed PET image using non-filtering OSEM

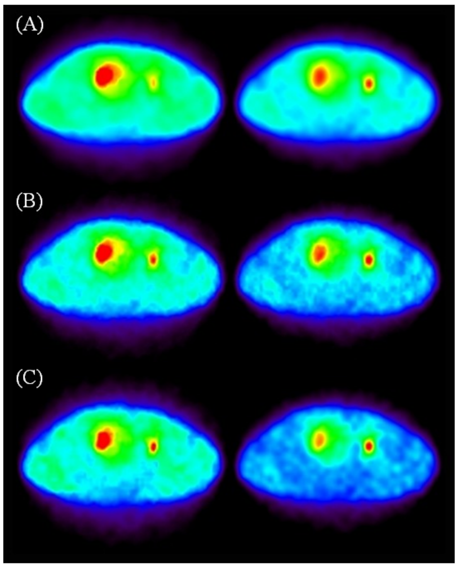


Fig. 3. (A) PET image using inter-iteration median (left) and Separable convolution (right) OSEM. (B) PET image using inter-update median (left) and Separable Convolution (right) OSEM. (C) PET image using median (left) and Separable Convolution (right) post-filtering OSEM

The produced XCAT phantom was used to GATE simulation and output data was reconstructed by OSEM algorithm and result images are described in Fig. 2 and filtered PET images are described in Fig. 3.

Table I: Uniformity and resolution of PET images

| | | Uniformity | Resolution |
|---|---|---|---|
| Non-filtering | | 0.40 | 4.66 |
| Inter-update | Median | 0.18 | 5.94 |
| | Separable Cartesian Metz | 0.41 | 5.42 |
| | Separable Convolution | 0.20 | 6.13 |
| Inter-iteration | Median | 0.13 | 6.50 |
| | Separable Cartesian Metz | 0.43 | 5.54 |
| | Separable Convolution | 0.14 | 7.08 |
| Post-filtering | Median | 0.22 | 5.37 |
| | Separable Cartesian Metz | 0.34 | 5.51 |
| | Separable Convolution | 0.22 | 6.10 |

Estimated uniformity and resolurion of PET images are described in Table I. Each filtered PET image was evaluated considering both of uniformity and resolution change rate to non-filtering.

### 3. Conclusions

The XCAT phantom was produced and it was used for GATE simulation. PET image was reconstructed using OSEM algorithm with different filters to compare the effect. The inter-update median filtering showed increasement of 55.00% and decreasedment of 27.47% for uniformity and resolution, respectively. Uniformity and resolution of PET image was dependent on part to where the filter was applied and it was verified in this study. Filtered PET image is expected to improve for diagnosis and treatment.

### REFERENCES

[1] M. Mahesh, T. J. Beck, E. C. Frey, and B. M. W. Tsui, Realistic CT simulation using the 4D XCAT phantom, Medical Physics, Vol. 35, No. 8, pp.3800-3808, 2008.

[2] R. Taschereau, P. L. Chow, and A. F. Chatziioannou, Carlo simulations of dose from microCT imaging procedures in a realistic mouse phantom, American Association of Physicists in Medicine, Medical Physics, Vol. 33, No. 1, pp.216-224, 2006.

[3] S. Jan, C. Comtat, D. Strul, G. Santin, and R. Trebossen, Monte Carlo Simulation for the ECAT EXACT HR+System Using GATE, IEEE Trans. Nucl. Sci., Vol. 52, Iss. 3, pp.627-633, 2005.